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Leeds & Northrup Portable Cable Testing Apparatus

The Leeds & Northrup Co.

Makers and Dealers
Electrical Measuring Instruments

259 North Broad Street
Philadelphia

20—904

Max Freimark

Fisher Cable Testing Set, No. 1

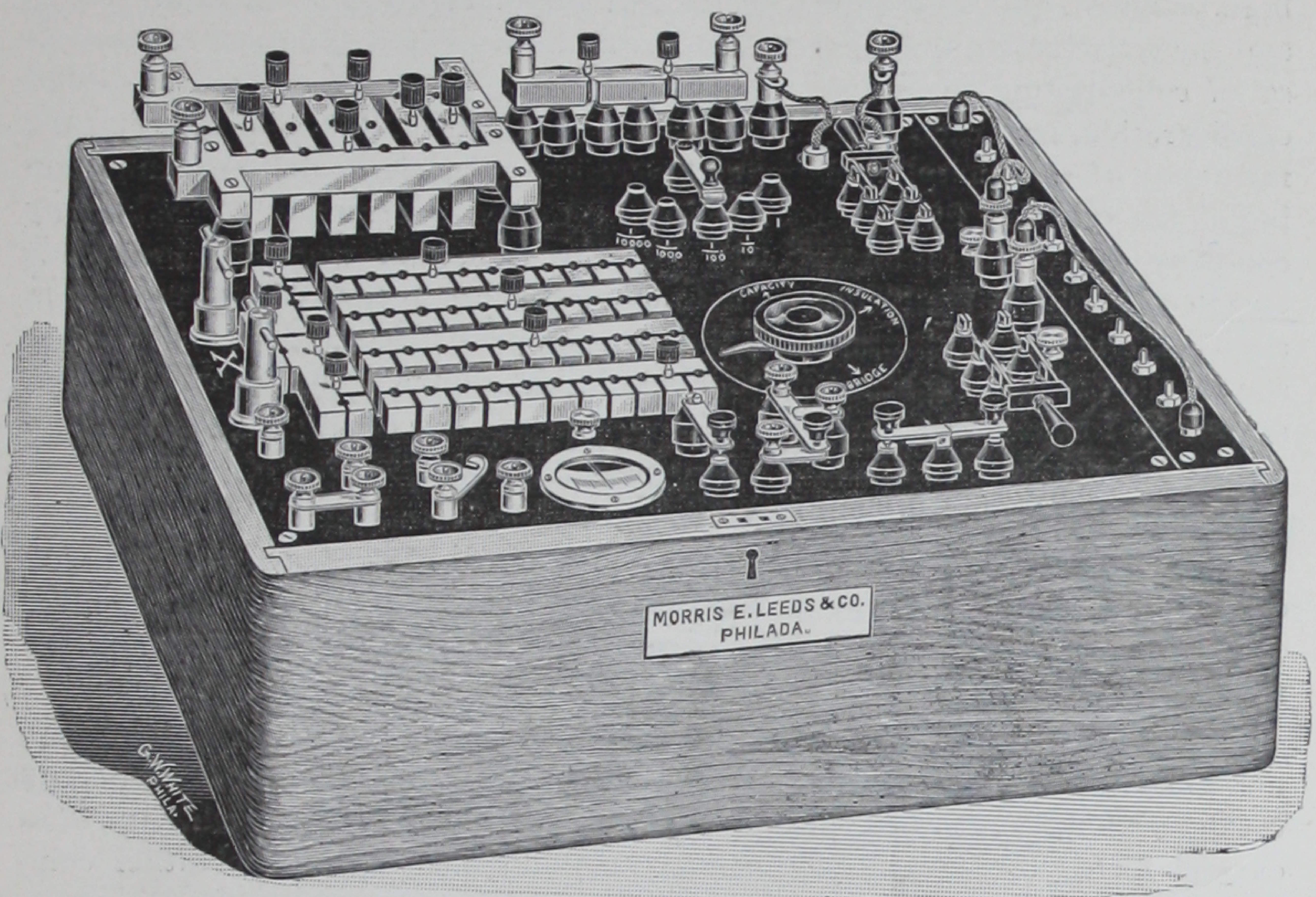


FIG. 1. B5352 (with cover removed.)

5352. Fisher Cable Testing Set, No. 1 . . . . $450 00
5353. Canvas Carrying Case for same, Fig. 6. . . . . 17 50

We offer the No. 1 Fisher Cable Testing Set as the very best combination Cable Testing Set that can be made. It is designed and constructed so as to insure—

Maximum Insulation,

Facility of manipulation never before equalled in this class of apparatus,

A very wide range of measurements. These include

- Electrostatic Capacity,
- Insulation Resistance,
- Conductor Resistance,
- Murray Loop Method of Locating Faults,
- Varley Loop Method of Locating Faults.

The Master Switch is the most distinguishing feature of the set. By means of it the connections can be made for the various tests by a single movement, thus avoiding the labor and time which have to be expended in interchanging the connections and memorizing the rather complicated scheme of connections.

This set was designed originally by Mr. Henry W. Fisher for the Standard Underground Cable Company, and the first two sets which we made are now in use by that company. The set has a number of original features which have been patented, and we are the sole licensed manufacturers. In both the design and the construction the aim has been to produce the best and most convenient set of cable testing apparatus that could be made. Every detail has had careful consideration, and each part has been designed with the aim of securing the maximum of simplicity, accuracy and convenience of manipulation. In speaking of the occasion for the design of the set, Mr. Fisher says :* "When my company decided to build two new factories it became necessary to provide excellent facilities for testing, and having in mind several improvements in addition to the above described testing arrangements, the author immediately started the design of a self-contained testing set which could be used to great advantage for portable purposes. The primary object was to have as few connections as possible, and to carefully consider the design of every part so as to insure simplicity of operation and a long life."

DIRECTIONS. To assist the user, complete directions are furnished with each set. They are the same as those printed hereafter and include a diagram of the connections, table of condenser capacities, resistance of galvanometer and resistances of shunt.

MASTER SWITCH. The most distinguishing feature of the set is a master switch by means of which the **connections can be made for the various tests by a single movement,** thus avoiding the labor and time which have to be expended in interchanging the connections and memorizing the rather complicated scheme of connections.

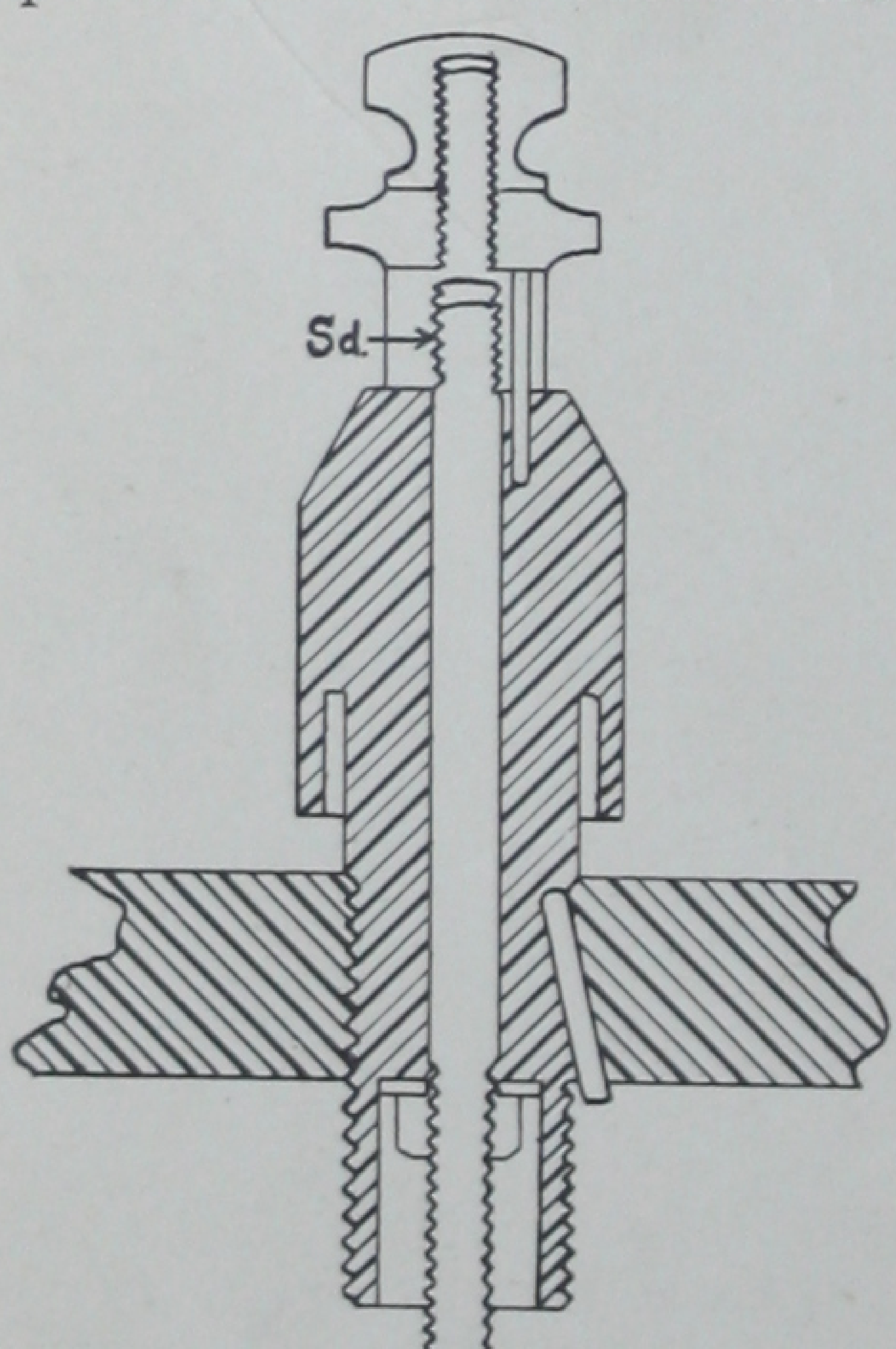


Fig. 2.

In the plan of connections, Fig. 7, the entire central part lettered A to D‴ represents this switch. In following out the connections on this diagram it is to be understood that when the pointer indicates capacity, the point A is connected to A′; B to B′, C to C′, and D to D′, and in the same way when "Insulation" and "Bridge" are indicated the points under them are connected. The connections in the switch are of the knife and jaw type and are thoroughly reliable. The master switch can readily be taken apart for cleaning or inspection.

HIGH INSULATION. In a set which is to be used out-doors and frequently in damp places, it is very important that ample insulation be provided. This has been accomplished by mounting all the parts which have to be protected on **specially designed hard rubber pillars.** A section of one of these is shown in Fig. 2. It will be seen that

* See article "Special Apparatus for testing Cables rapidly and accurately."—*Electrical World and Engineer*, May 12, 1900.

ample surface is secured to prevent leakage both above and below the hard rubber plate on which the apparatus is mounted, and that the advantages of the petticoat type of insulator are secured in each place. In this class of apparatus trouble has frequently been experienced by leakage from the hand of the operator when using the keys. This is overcome by the use of a special hard rubber button, having some of the features of the insulating pillar. This is shown in section in Fig. 3.

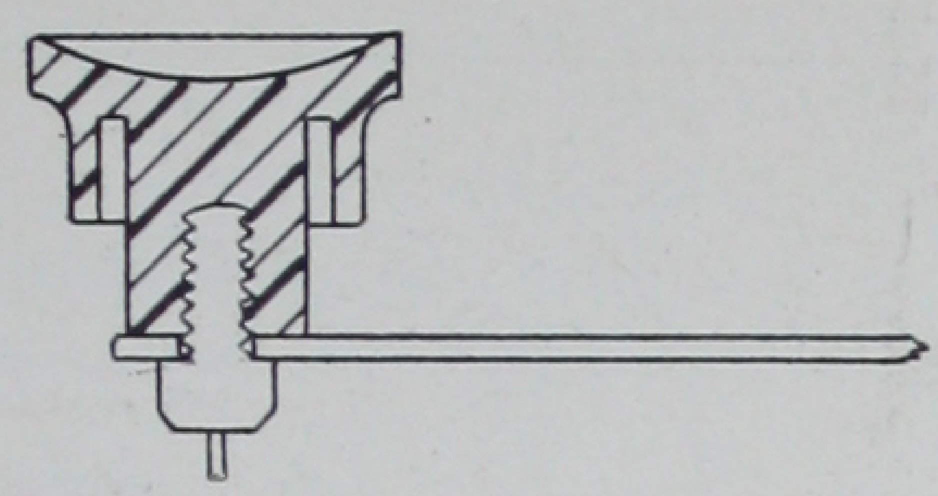


FIG. 3.

CONNECTIONS between the different instruments composing the set are made in all cases by means of heavy bare copper wires which are run through the air from the brass rods projecting through the insulating pillars, the connecting wires are securely fastened by binding against the brass rods with small copper wire, and soldering. They are run at such a distance from each other that there is no danger of their touching. In this way three very important points are secured. **The insulation is very high and will not degenerate,** as might happen if covered wires were depended on. **All of the connections are very easily inspected. Thoroughly reliable contacts are insured.**

THE BATTERY is 10 cells, of a special type of semi-dry cell which has an e. m. f. of about 1.5 volts per cell when new. It is connected to the Battery posts by means of flexible leading wires.

THE BATTERY AND GALVANOMETER REVERSERS are the double-throw, double pole type of switches, and are very neatly mounted. They serve both as reversers and as a means of breaking the circuit to which they are attached. With this style of switch there can be no possible question of a bad contact, which is often the case with some types of reversing switches.

THE GALVANOMETER is our standard form for use in testing sets and other portable apparatus. It is characterized by **high sensibility** (one volt through 1 megohm will cause a deflection of about 1 mm. on its scale) and **robust construction.** It will stand as much rough usage as an ordinary millivoltmeter. It is amply sensitive for measurements of conductor resistance and for locating faults, except where there is a high resistance in the fault. For many tests this galvanometer is amply sensitive and it is not necessary to take an outside galvanometer.

THE 1-10 MEGOHM is made of two coils of 30,000 and 70,000 ohms respectively, and is provided with plugs by which one or both can be cut out. It is also provided with binding posts at each end, so that if necessary it can be used apart from the set.

THE SHUNT is of the Ayrton Universal type, and hence can be used with galvanometers of any resistance. In addition to general practice it is provided with a $\frac{1}{10000}$ shunt, and therefore under ordinary conditions can be used with very sensitive galvanometers where the insulation constant of the galvanometer may be several hundred thousand megohms with 100 volts.

THE KEYS are mounted on insulating pillars as described above and are carefully designed and constructed to insure permanent alignment of contacts.

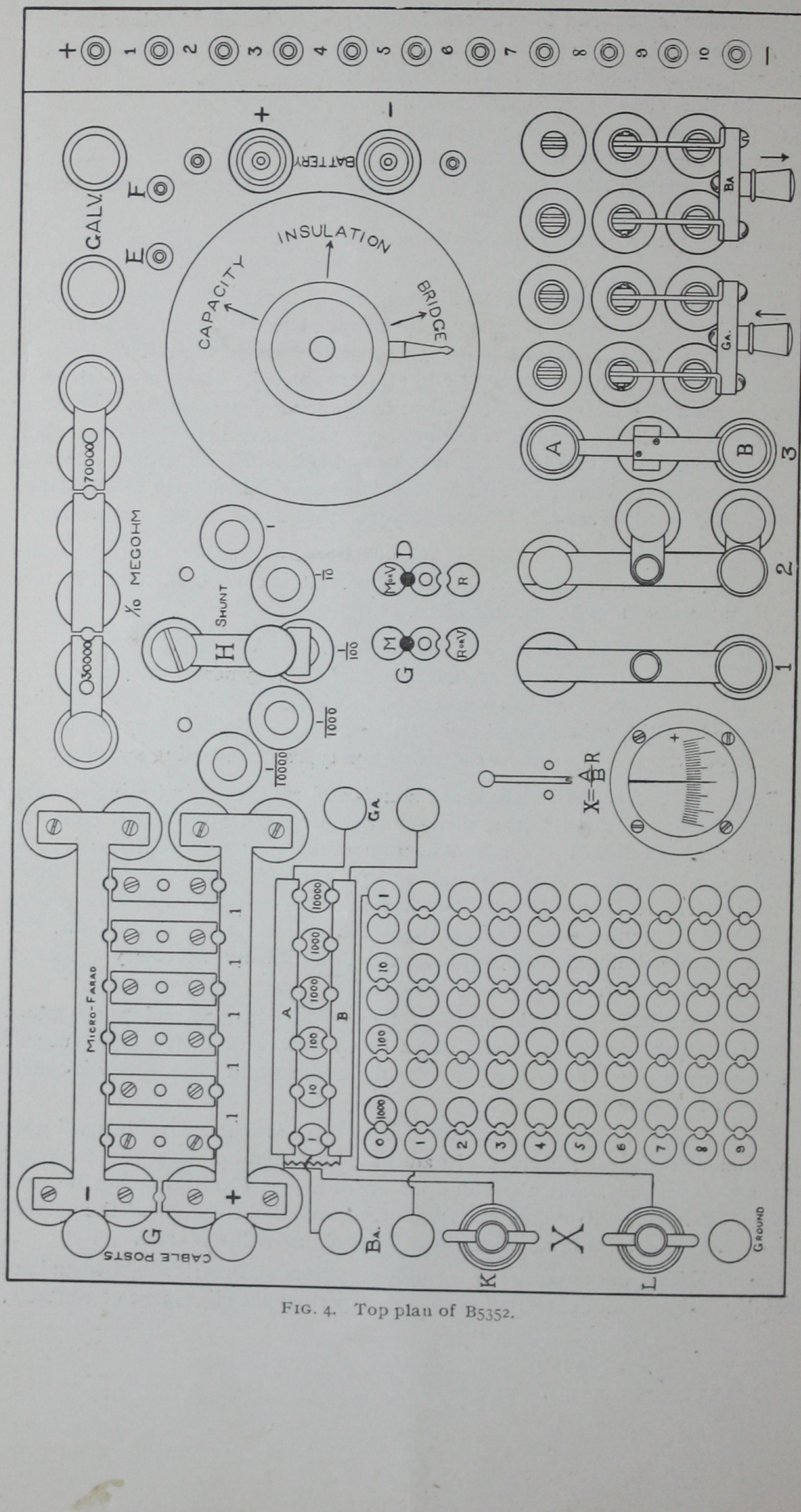


FIG. 4. Top plan of B5352.

The short circuit key is arranged so that it can be instantly changed from a permanent to a tapping short circuit. By pressing down the button A a permanent short circuit is made through a knife and jaw. B is attached to a strip of spring brass, underneath which is a rigid arm. When B is depressed it first bends the spring, then coming in contact with the rigid arm opens the circuit at A and immediately afterwards makes it at B by bringing two platinum contacts together. This contact opens as soon as the spring is released and forms the tapping short circuit.

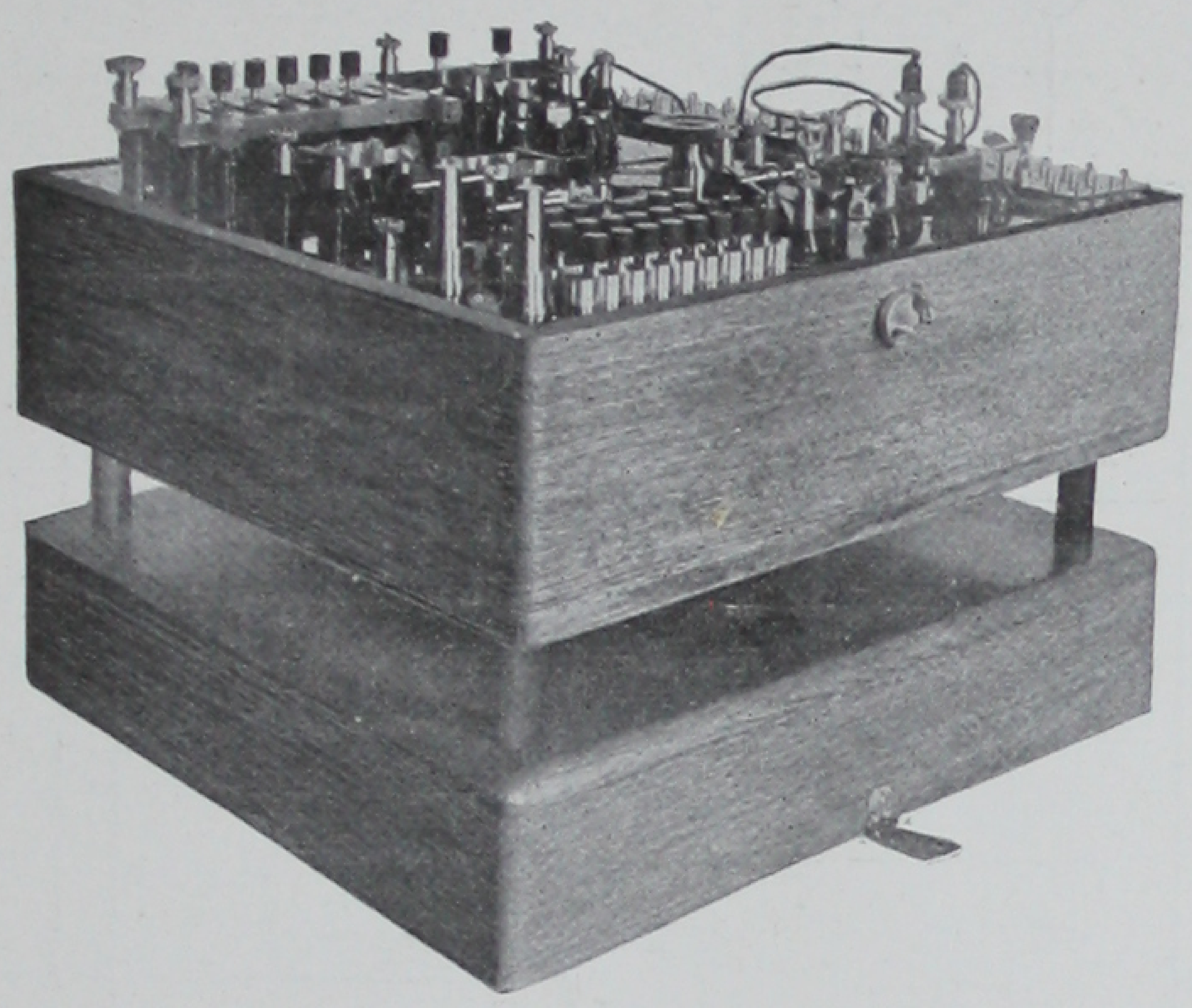


Fig. 5.

THE CONTAINING CASE is substantially made of well finished hard wood. The lid is fastened in place with a special type of hinges which allow it to be entirely removed. Four hard rubber pillars are provided so that the set can be mounted upon the lid as shown in Fig. 5 and thus thoroughly insulate it as a whole from the ground.

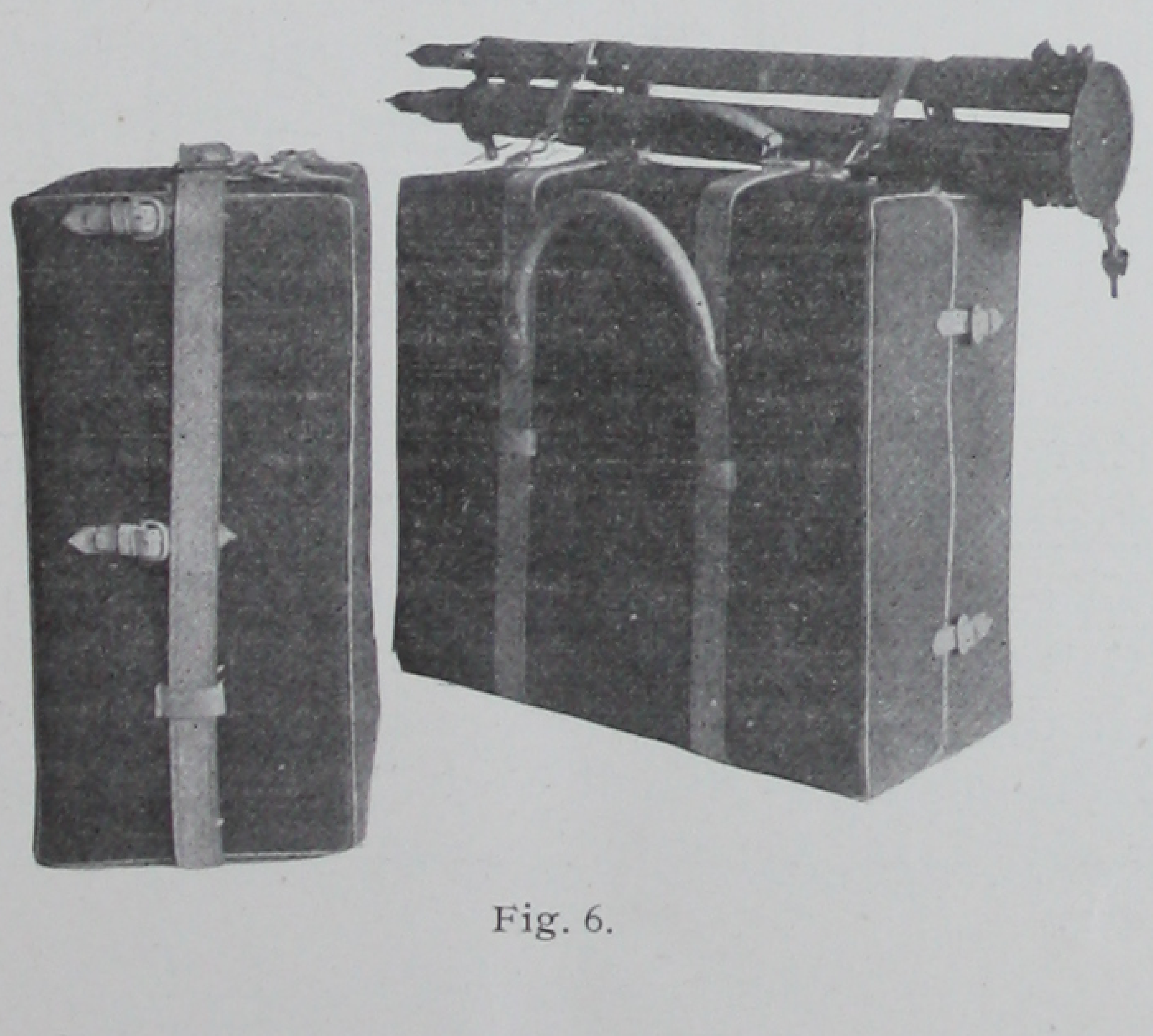


Fig. 6.

The outside dimensions of the case are, length, 21½; width, 13½; depth, 9½ inches. It weighs about 45 lbs.

THE CANVAS CARRYING CASE is shown in fig. 6. This is Catalogue No. 5353 and is not furnished with the set unless ordered. Fig. 6 shows the No. 1 Fisher set to the right and on it the tripod of galvanometer No. 5369 which is in the case to the left.

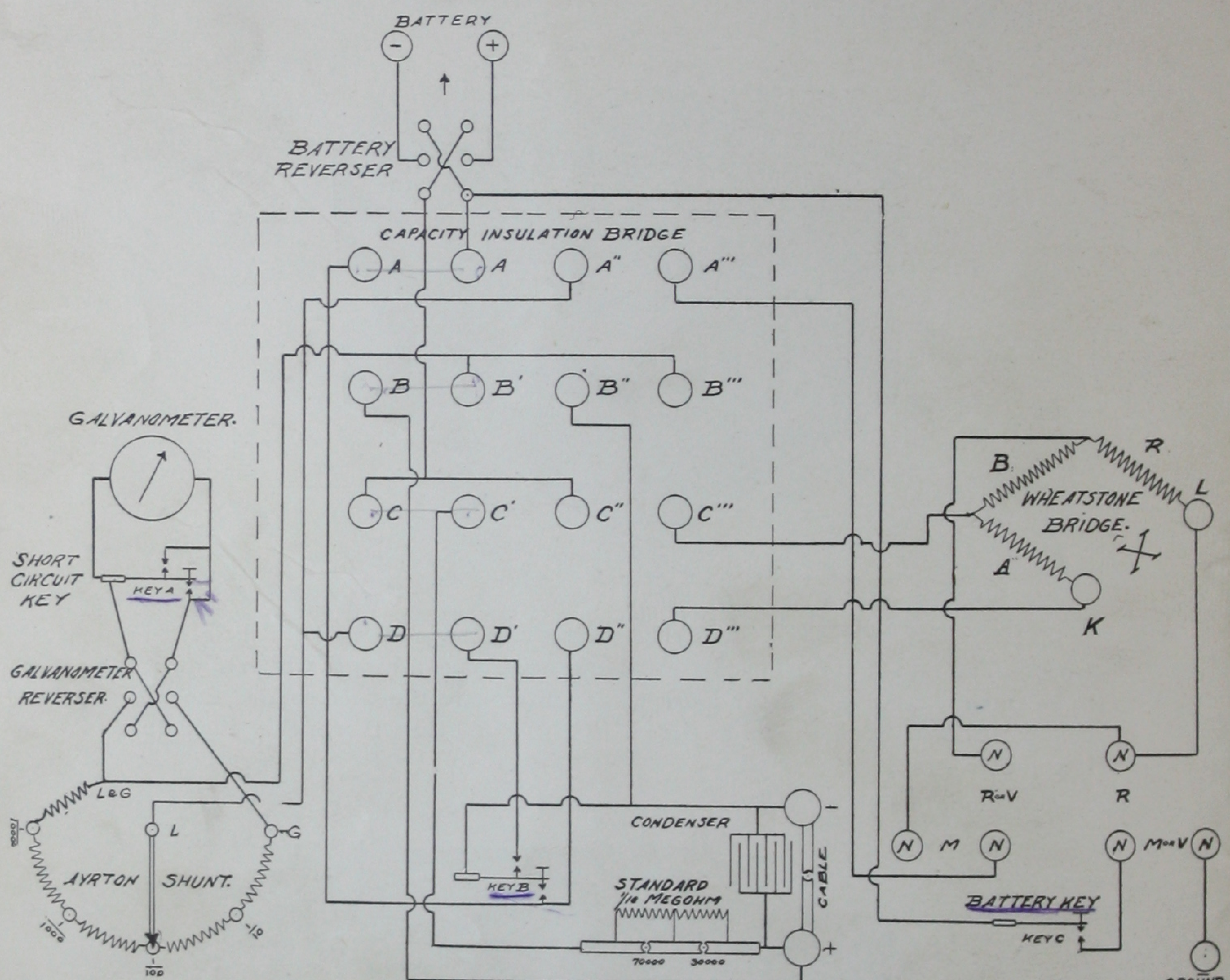


Fig. 7.

Directions for Operating Fisher Cable-Testing-Set, No. 1.

MEASUREMENTS OF ELECTRO-STATIC CAPACITY. Connect a reflecting galvanometer (such as our No. 5369 Portable Reflecting Galvanometer Type H) to "Galvanometer Posts" and a few cells of battery to "Battery Posts." Connect the two leading wires, running from the conductor of the cable, and from the ground, to "Cable Posts." Place the shunt arm H at 1 and the master switch at "Capacity." Close the galvanometer and battery reversing switches.

The test can now be made in the ordinary manner as follows :—

Press down key number 2 for about ten seconds, or whatever the required time of charging may be, and the instant before releasing it, press down all the way and release button B of key 3 to remove the short-circuit from the galvanometer ; then key 2 can be released and the discharge deflection of the galvanometer read. If it is too small apply more battery till a sufficiently large discharge deflection is obtained, which record. Next disconnect the cable leading wire from the conductor, and in like manner measure the discharge deflection due to the leading wires. Then, without in any way changing or disconnecting the leading wires, plug in a sufficient amount of condenser capacity to give a discharge deflection as nearly as possible equal to that of the cable. Plugs should not be jammed into condenser as in rheostat as it is not necessary and may strain the blocks. After a number of plugs have been inserted in condenser they should be gone over to see that all are tight.

To obtain the *true* discharge deflections of cable and condenser, subtract the discharge deflection due to the leading wires from the observed discharge deflections of cable and condenser.

Then letting,

c=The amount of condenser capacity used,
d=The true discharge deflection due to the cable,
d'=The true discharge deflection due to the condenser,
L=The length of cable in feet.

The absolute capacity of the cable$= \frac{d \times c}{d'}$

and the capacity per mile of cable$= \frac{d \times c \times 5280}{d' \times L}$

In order to prevent the e. m. f. of the battery from changing in case of a test being made when the leading wires were accidentally crossed or the cable grounded, the cable or condenser is normally charged through the $\frac{1}{10}$ megohm box, but, if desirable, part or all of said resistance can be cut out by inserting plugs across the 30000 or 70000 ohms. For most purposes it is sufficient to have the 30000 ohms in circuit.

MEASUREMENTS OF INSULATION RESISTANCE. Connect a reflecting galvanometer (such as our No. 5369 Portable Reflecting Galvanometer Type H) and a battery of 50 or 100 cells to their respective posts, and connect the two leading wires from the cable conductor and from the ground to "Cable Posts." Close the battery and galvanometer reversing switches and see that button A of key "3" is pressed down to short-circuit the galvanometer.

The test can now be started by placing the special switch at "Insulation," noting while doing so the time. Shortly before the period of electrification, which is generally one minute, has elapsed, press down button B of key "3" and keep tapping it, thereby intermittently short-circuiting the galvanometer and consequently checking the too sudden movement of the galvanometer needle. Finally when the needle has come to rest the deflection is read at the end of one minute. Then disconnect the leading wire from the cable and in like manner measure the deflection due to the leading wires which

must be subtracted from the observed deflection first read to give the *true* deflection due to the cable. During this test the shunt arm H can generally be placed at "1" but when the insulation is low the $\frac{1}{10}$ or $\frac{1}{100}$ shunt may have to be used, when the deflection is multiplied by 10 or 100 respectively to get the true deflection.

The insulation constant of galvanometer is next determined as follows; Remove both plugs from the $\frac{1}{10}$ megohm box so as to have the 100,000 ohms in circuit, insert a plug at G, place the shunt at $\frac{1}{10000}$ and in the same manner mentioned above note the deflection. If said deflection is too small apply the $\frac{1}{1000}$ or $\frac{1}{100}$ shunt till a good readable deflection is obtained, which we will call$=D'$.

Then the insulation constant of galvanometer$=\frac{D'}{10\times \text{Shunt used}}=G$

Letting

$D=$The true deflection due to the cable.

$L=$The length of the cable in feet.

Then the absolute insulation resistance of the cable$=\frac{G}{D}$

And the insulation resistance per mile$=\frac{G\times L}{D\times 5280}$

It is also best to make the regular resistance tests with the .1 megohm in series, and where great accuracy is desired .1 megohm can be subtracted from calculated absolute insulation resistance to get the true absolute insulation resistance. This is advised so that the battery can never be short circuited. The horizontal galvanometer can be used for this work by connecting it to the "Galvanometer Posts" through the flexible connectors E, F.

DETERMINATIONS OF ELECTRIC POLARITIES. When the constant of galvanometer, above mentioned, is taken with the handles of the battery and galvanometer reversers pointing towards the arrow heads and the plus and minus sides of the battery are connected as marked at "Battery Posts," (See Fig. 4) the corresponding polarities are found as marked at "Cable Posts" and the galvanometer needle deflects towards the plus sign.

To measure unknown polarities therefore, such as those of electric street railway currents on water pipes or cables, connect the wires from the terminals whose polarities are desired, to the "Battery Posts" and making the connections in the manner just mentioned the plus terminal can be immediately determined.

Uses of the Wheatstone Bridge.

MEASUREMENTS OF CONDUCTOR RESISTANCE. Place the master switch at "Bridge;" connect the horizontal galvanometer flexible leading wires E and F to "Galvanometer Posts;" connect a few cells of battery to "Battery Posts," as indicated by plus and minus signs; place the plugs C and D in the positions marked R; place the galvanometer and battery reverser handles in the directions of the arrow heads; press down the button B of key 3 to remove the short circuit from the galvanometer, and connect the wire whose resistance is desired to the posts K and L of X.

The test can now be made in the regular manner by pressing down keys

1 and 2, a deflection of the galvanometer needle towards the plus mark indicates that the resistance in the rheostat must be increased to give a balance.

In the "Decade" form of Bridge, resistances are put in circuit by inserting plugs. One plug, therefore, is used to connect one ratio coil to A and a second to connect another ratio coil to B. Four plugs are used in the rheostat, one for each set of units, tens, hundreds and thousands.

When a low resistance has to be measured, connect as above described, a low resistance to A and a high resistance to B. When measuring a high resistance connect a high resistance to A and a low one to B. The $\frac{1}{100}$ shunt can be used at first and the 1 shunt for the final adjustment.

Letting,

A=The resistance connected to bar A,
B=The resistance connected to bar B,
R=The rheostat resistance that gives a balance of the galvanometer,

Then the resistance between K and $L = \frac{A}{B} \times R$

MURRAY LOOP METHOD OF LOCATING GROUNDED OR CROSSED WIRES. The Murray Loop is the simplest method of locating grounds and crosses and is applicable when the faulty and good wire are of the same material, size and length. Hence it can be used to locate such faults in telephone and telegraph cables, where all the conductors seldom become faulty before the method can be applied.

It can also be used in the case of electric light cables where the outgoing and incoming cables are of the same size and length and one of them is not faulty.

To apply this method join the faulty and good conductor at the distant end of the cable and connect the faulty conductor to L and the good one to K. Place the plugs C and D in the positions marked M and connect the ground or, in the case of a cross, the wire crossed with the one under test to the post marked "Ground." It is best to start with Bar B, connected to 1 ohm and A connected to 1000 ohms.

Having connected a few cells of battery the resistance in the rheostat can now be varied till a balance is obtained in the same manner described under "Measurements of Conductor Resistance."

But in order that a deflection of the galvanometer needle towards the plus mark may mean that the rheostat resistance must be increased, it will be necessary to place the handle of one of the reversing switches in a direction opposite to that indicated by the arrow head.

Letting

A=The resistance connected to bar A,
B=The resistance connected to bar B,
R=The resistance in the rheostat required to give a balance,
L=The length of cable=½ the length of conductor,

Then the distance to the fault$= \frac{2 \times (B + R)}{A + B + R} \times L$

A check test can be applied by connecting the faulty wire to "K" and the good one to "L," and then varying the rheostat resistance till a balance is

obtained. If a balance cannot be obtained with "A" connected to 1000, it will have to be connected to 100 or 10.

Letting,

A'=The resistance connected to bar A,

B'=The resistance connected to bar B,

R'=Resistance in the rheostat required to give a balance,

Then the distance to the fault$= \frac{2 \times A'}{A' + B' + R'} \times L$

If the tests are made on a loop of wire the total length of which only is known, then said length must be substituted for L and the two removed from the numerators of the above formulæ. One end of the wire should be tagged, and when this end is connected to L the first formula will give the distance to the fault from said end, and the second formula will do likewise when the tagged end is connected to K. When applying the Murray loop test it is customary to make B or B'=O, but as this cannot be done with the Decade Bridge, formula involving B and B' are given.

If the resistance of the fault be high it may be necessary to use 50 or more cells of battery.

VARLEY LOOP METHOD OF LOCATING CROSSED OR GROUNDED WIRES. Place the plugs C and D in the positions marked V. Join the grounded and good wire at the distant end of the cable and connect the former to L and the latter to K. Connect the ground, or in the case of a cross, the wire crossed with the one under test to the post marked "Ground."

Bar A should generally be connected to either 10 or 100 ohms and Bar B to 1000 ohms.

After connecting a few cells of battery a balance can now be obtained by varying the rheostat resistance till the right amount is applied.

Letting,

A=The resistance connected to bar A,

B=The resistance connected to bar B,

R=The rheostat resistance which gives a balance.

r=The total measured resistance of the loop, which should be measured, as described under "Measurements of Conductor Resistance."

Then the resistance to the fault from L $= \frac{B \times r - A \times R}{A + B} = a$

Connect now the faulty wire to K and the good one to L and letting A', B' and R' represent the new values of A, B and R, we have by a check method,

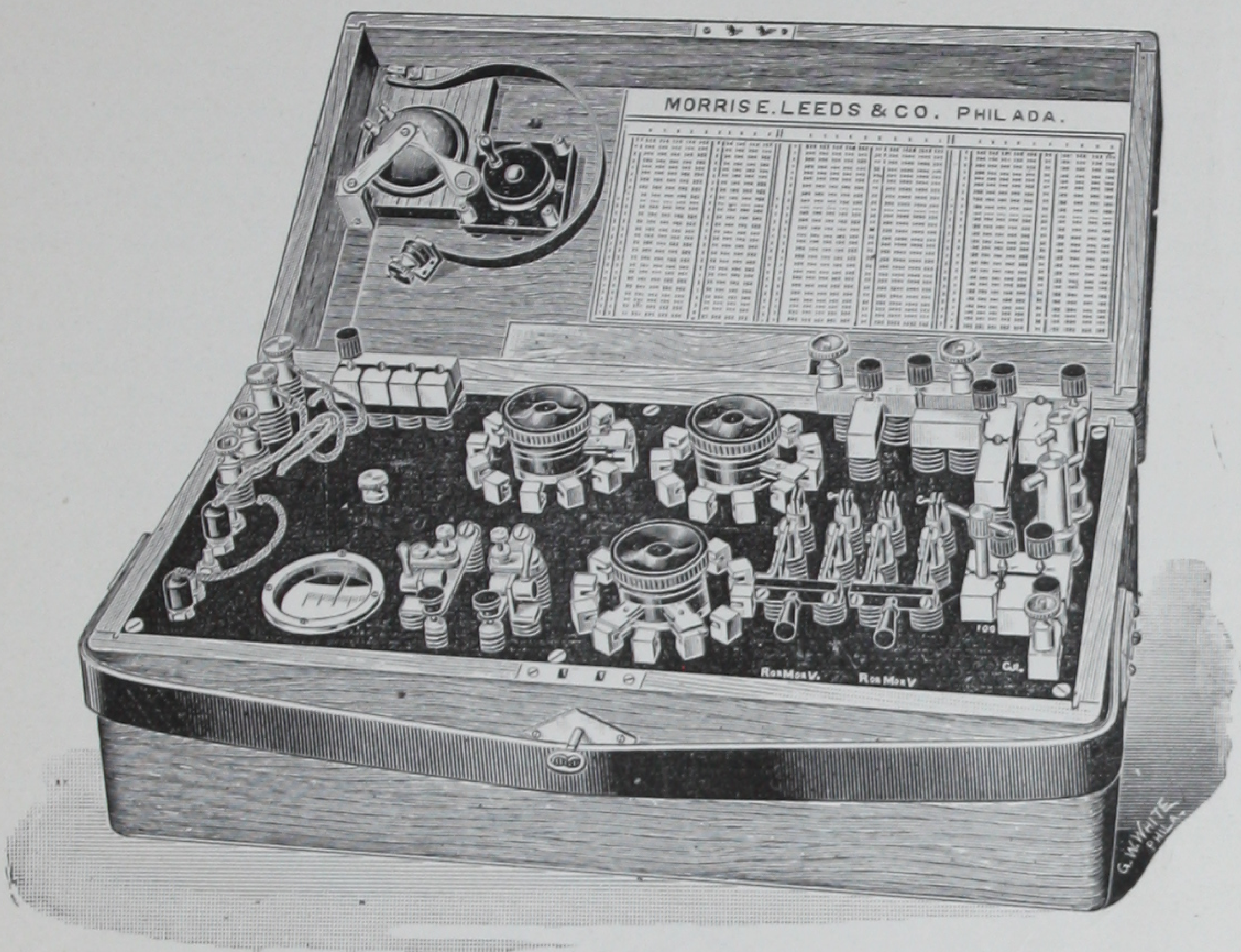
The resistance to the fault from K $= \frac{A' \times (r + R')}{A' + B'} = a'$

Letting b = the resistance of the faulty wire=½ the resistance of the loop, where good and bad wires are of the same size and are in one cable, and letting L=the length of the cable, then

The distance to the fault$= \frac{\frac{1}{2}(a + a')}{b} \times L$

When dealing with faults of high resistance 50 or more cells of battery may have to be used.

Fisher Cable Testing Set, No. 2.



B5358.

B5358. Fisher Cable Testing Set, No. 2 . . . . $250 00

The No. 2 Fisher Cable Testing Set is a compact, substantially made and conveniently portable apparatus for

Locating Faults, Grounds and Crosses,
Locating Breaks in Cables,
Conductor Resistance Measurements,
Insulation Resistance Measurements,
Capacity Measurements.

New features specially designed for this set greatly simplify the measurements and calculations for fault location.

This set, like the No. 1, was originally designed by Mr. Fisher for the use of the Standard Underground Cable Company, and as in that case the first set made was used by that company. It is intended for work where a strictly portable set is required, and is consequently much smaller and weighs proportionally less than No. 1. As it will frequently be used for hunting trouble, a special arrangement of the bridge has been adopted so as to greatly facilitate *Murray & Varley Loop Tests for Faults*.

NEW AND VALUABLE FEATURES. Mr. Fisher has also introduced

a method new to portable cable-testing sets **for locating breaks in cables where the conductor has parted;** and, in addition to the usual one, a new method for measuring capacity in which no galvanometer is required, a telephone being used in place of it.

To accomplish the reduction in size and weight it has been necessary to sacrifice some of the features of the No. 1 set. A single condenser of three-tenths M. F. is used instead of the sub-divided standard and the one-tenth megohm is in a single instead of two parts. The parts are mounted on corrugated hard-rubber pillars, which extend above and below the base, instead of the special petticoat type.

This arrangement gives a **very good insulation,** and one that will be found entirely satisfactory, except under the most trying conditions of moisture. Much time and thought have been expended on this set both by Mr. Fisher and ourselves to make insulation and all other features the best possible within the prescribed limits of size and weight. As in the No. 1 set, **the changes from one test to another are accomplished very easily** and without the use of inconvenient flexible cords. They are effected by double-throw switches which are plainly marked so that it is not necessary to memorize a complicated scheme of connections.

THE STANDARD OF CAPACITY has a single value of $\frac{3}{10}$ microfarad.

THE STANDARD HIGH RESISTANCE is 100,000 ohms, and is also a single value, not sub-divided.

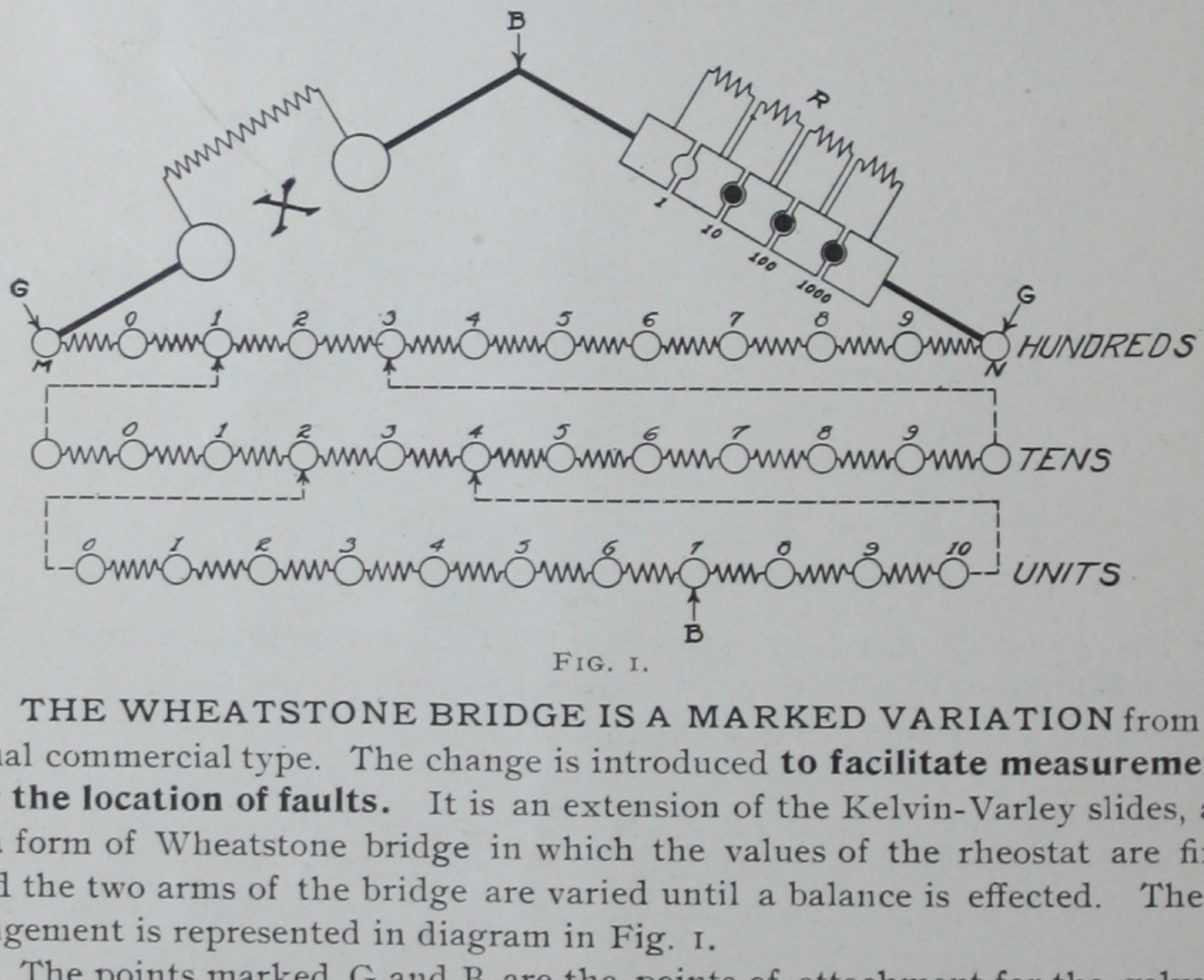


FIG. 1.

THE WHEATSTONE BRIDGE IS A MARKED VARIATION from the usual commercial type. The change is introduced **to facilitate measurements for the location of faults.** It is an extension of the Kelvin-Varley slides, and is a form of Wheatstone bridge in which the values of the rheostat are fixed and the two arms of the bridge are varied until a balance is effected. The arrangement is represented in diagram in Fig. 1.

The points marked G and B are the points of attachment for the galvanometer and battery. At R are represented the four coils of the rheostat, any one of which may be used, and at X the unknown resistance. Between M and

N are eleven coils of equal value which form the bridge wire. There is a contact point between each coil and the one next to it. The other coils shown in the series marked "Tens" "Units" are used to sub-divide the coils of the bridge. They constitute what may be called an electrical vernier, by means of which the bridge wire is sub-divided to thousandths of its total value. The two arrows in contact with the points marked 1 and 3 in the "Hundreds" row and with the 2 and 4 in the "Tens" row represent contact arms which can be moved along to make contact at any of the contact points, but are always at the same distance apart so that they have two coils between them. They are connected to the ends of the row of coils below them so that these two coils are shunted with the entire row of coils below. Consider now the result of this shunting in the case of the "Tens" and "Units" coils. The tens are, for example, eleven coils of 80 ohms each. The units are ten coils of 16 ohms each. The two 80 ohm coils between the points 2 and 4 are shunted with the ten 16 ohm coils; 160 ohms is shunted with 160 ohms, and the resistance between the points 2 and 4 becomes 80 instead of 160 ohms. There are then in the "Tens" series, for any position of the double arms, actually ten resistances of 80 ohms each. The point of the galvanometer contact may be placed at any position in the "Units" series, thus sub-dividing the shunted coils in the "Tens" series to tenths. The coils in the "Hundredths" series are 400 ohms each, and are subdivided in the same way by those in the "Tens" series. An example will make the use of the bridge clear. Assume that a balance is obtained with 100 unplugged in the rheostat and the contacts in the position shown. The bridge reading is then 237. Call this value A. Then

$$X : R :: A : 1000 - A, \text{ and } X = R \frac{A}{1000-A} = 100 \frac{237}{763} = 31.06$$

The calculation of the fraction $\frac{237}{763}$ would take considerable time, and might lead to errors. To overcome the necessity for this we furnish, conveniently fastened into the lid of each set, a table giving the values of $\frac{A}{1000-A}$ for all values of A between 0 and 1000. Reference to the table shows $\frac{A}{1000-A} =$ .3106 for A = 237. We have, consequently, simply to multiply the value taken from the table by the resistance unplugged in the rheostat to determine the value of X. From this it will be seen the Wheatstone Bridge measurements may be made and calculated very rapidly.

In the actual construction the coils are arranged in three dials. The contact arms and points are constructed so as to insure good contacts.

From the plan Fig. 2 and the diagram Fig. 3 the arrangement and connection of the different instruments making up the set will be evident. Complete information in regard to the measurements for which the set may be used can be obtained from the following directions.

Directions for Operating the Fisher Cable Testing Set, No. 2

MEASUREMENTS OF ELECTROSTATIC CAPACITY. In making tests of this nature a Reflecting Galvanometer should be employed, because the Galvanometer of the testing set is not sufficiently accurate, nor has it a long

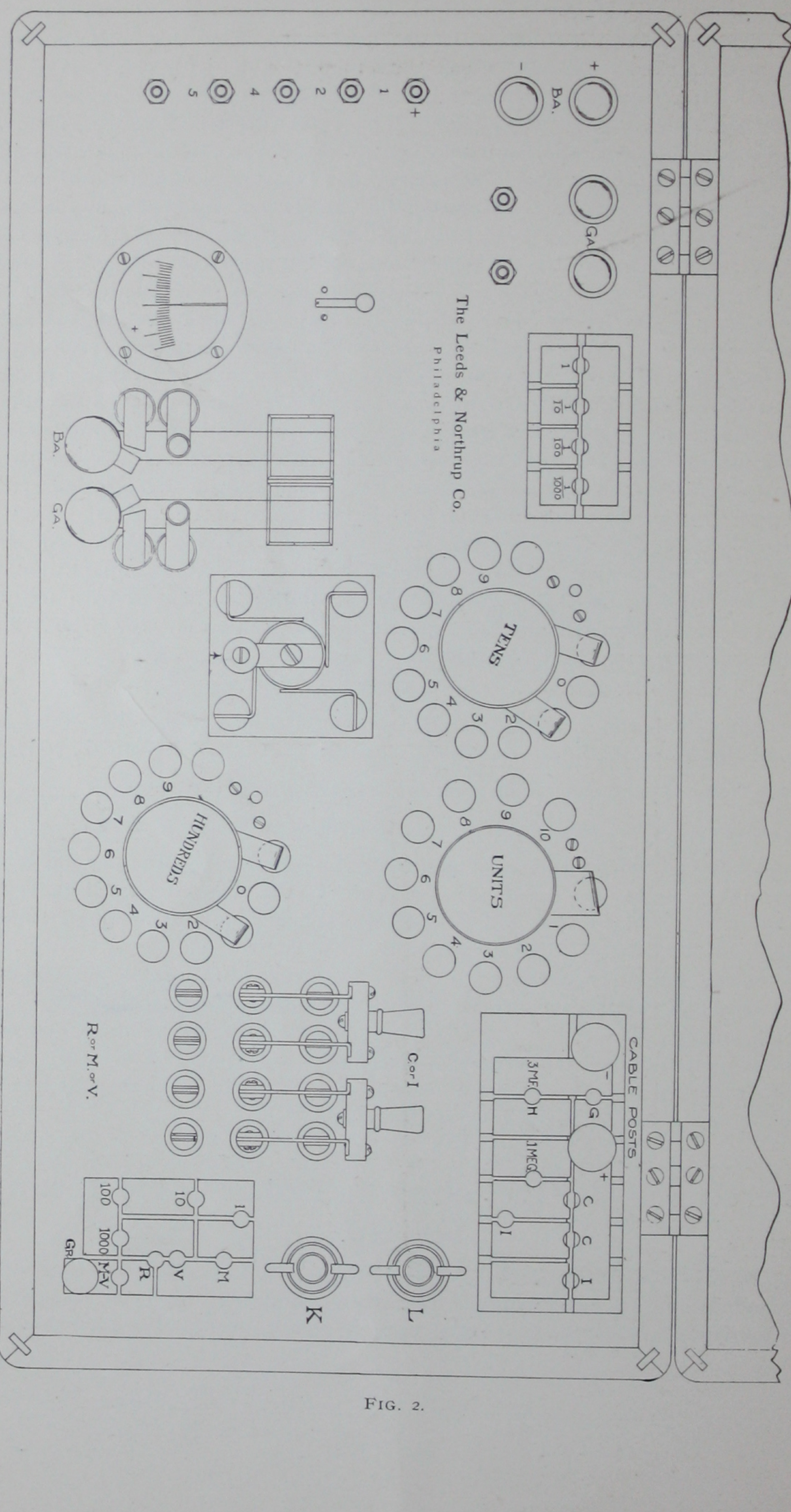

The Leeds & Northrup Co.
Philadelphia
BA.
GA.
TENS
UNITS
HUNDREDS
CABLE POSTS
C or I
R or M or V.
K
L

FIG. 2.

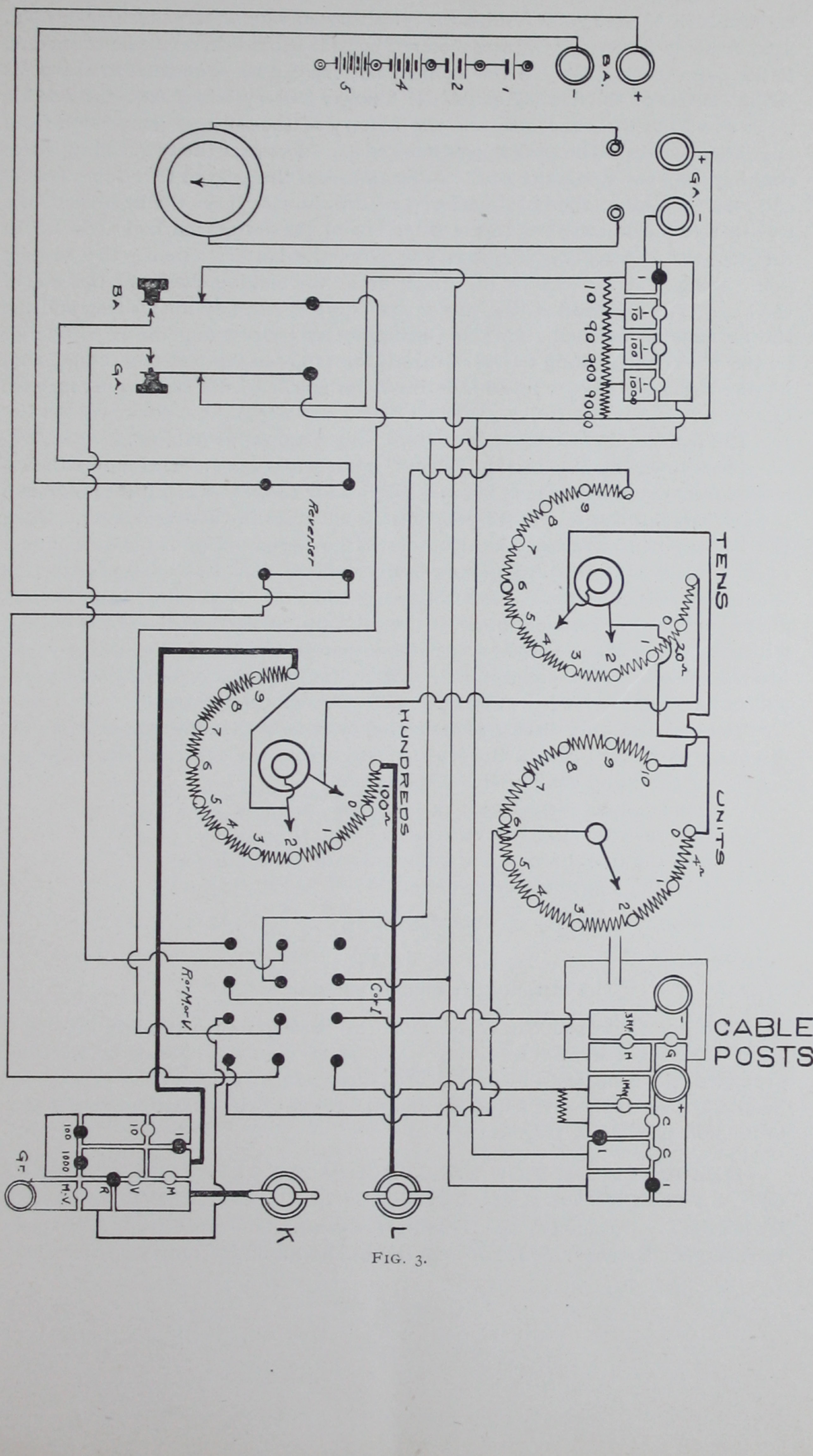


FIG. 3.

enough scale to give good results. A reflecting galvanometer, (such as our No. 5369 Portable Reflecting Galvanometer, Type H) should therefore be connected to the posts marked Ga. A few cells of battery can be connected to the posts Ba, by means of the flexible cords. If a larger battery is required the flexible cords should be disconnected from the battery of the set, and connection from any other battery made to the posts marked Ba. Connect the two leading wires running from the conductor of the cable and from the ground to "Cable Posts" and insert a plug in the hole marked 1 of the shunt. Place the handles of the two double-throw switches in the direction of the letters marked C or I. In this test the key marked Ba. serves to close the battery circuit, the contact point being held in place by the finger or by the locking device at the side of the key. The key marked Ga. serves as a short-circuit key in this test, and the short-circuit is removed from the Galvanometer by pressing the key down or by the use of the locking device. Insert two plugs in the holes marked C, and be sure that no plugs are inserted in the holes marked I nor in the hole marked G.

The test can now be made in the ordinary manner, as follows:

Press down the key marked Ba. for about ten seconds, or whatever the required time of charging may be, and the instant before releasing it press down the key marked Ga. to remove the short-circuit from the Galvanometer. Then the Ba. key can be released and the discharge deflection of the Galvanometer read. If it is too small apply more battery until a sufficiently large deflection is obtained, which record. Next disconnect the cable lead wires from the conductor and in like manner measure the discharge deflection due to the leading wires. Then, without in any way changing or disconnecting the leading wires, insert a plug at H to connect the .3 M.F. condenser across the cable posts, and in like manner read the discharge deflection of the condenser.

To obtain the true discharge deflection of cable and condenser, subtract the discharge deflection due to the leading wires from the observed discharge deflection of cable and condenser. Then letting,

$c =$ amount of condenser capacity used $= .3$ M. F. in this case,
$d =$ the true discharge deflection due to the cable,
$d' =$ the true discharge deflection due to the condenser,
$L =$ the length of the cable in feet.

The absolute capacity of the cable $= \frac{d \times c}{d'} = \frac{d \times .3}{d'}$

And,

$$\text{The capacity per mile of cable} = \frac{d \times .3 \times 5280}{d' \times L}$$

In order to prevent the E. M. F. of the battery from changing in case of a test being made when the leading wires are accidentally crossed or the cable grounded, the cable or condenser is normally charged through the $\frac{1}{10}$ megohm box, but, if desirable, said resistance can be cut out of circuit by inserting a plug in the hole marked $\frac{1}{10}$ megohm.

MEASUREMENTS OF ELECTROSTATIC CAPACITY BY MEANS OF A TELEPHONE AND CONTINUALLY REVERSED BATTERY CURRENT. Disconnect the flexible Galvanometer wires from their posts marked Ga. Remove the flexible cord from the lid of set and attach terminals

of same to telephone and posts marked Ga. Place the shunt plug at 1, place the handles of both double-throw double-pole switches in the direction of the letters R or M or V, insert two plugs in the holes marked M. Plugs must not be inserted at either V or R. It is immaterial whether or not plugs are inserted in the resistances 1, 10, 100, or 1000. The keys marked Ba. and Ga. must be held down in place by means of their locking devices. Connect the cable to the post marked K and the lead of the cable or ground to the post marked Gr. and also to one of the posts marked "Cable Posts," connect the other cable post to the post marked L, remove all plugs from the holes marked C, I and G. Insert a plug in the hole marked H. The test can now be made in the following manner:

Place the rotating switches marked "Tens" and "Units" at zero. Then rotate the battery reversing switch (which is placed on the main plate to the right of keys). When the same is not used, the arrows on the side should always be made to coincide with the arrow stamped on the rubber plate, and having placed the telephone to the ear rotate the dial switch marked "Hundreds" until a point is found where the noise in the telephone is least. The next step is to rotate the switch marked "Tens" until the position is found which gives the least sound in the telephone. In like manner the "Units" switch is rotated until no sound is observable, when the required point of balance is reached.

It must be remembered that when the point of least sound is reached with any dial that the balance point may be either smaller or larger than the figure indicated. For instance, suppose the least sound occurs at the point 3 of the switch marked "Hundreds," and that the sound gets louder when the switch marked "Tens" is rotated, it is conclusive that the balance is less than 300, and hence the point 2 of the "Hundreds" dial must be used. In like manner discrimination must be used between the "Tens" and "Units" switches. When a balance is obtained write down the reading in the order of "Hundreds," "Tens" and "Units."

Letting said reading = A,
Letting C = Condenser capacity = 3 m. f. in this case.
Letting L = Length of cable in feet.

$$\text{The capacity of the cable} = \frac{A \times C}{1000 - A} = \frac{A \times .3 \text{ M. F.}}{1000 - A}$$

$$\text{The capacity per mile} = \frac{A}{1000 - A} \times \frac{.3 \times 5280}{L}$$

The value of the term $\frac{A}{1000 - A}$ is found in the accompanying table opposite the value of A.

This method is quite sensitive and can be readily applied. The results are slighly lower than those obtained by the first method because a cable, as a rule, electrifies rather more slowly than the condenser. The results by the second method will be more concordant when the time of charge by the first method is made equal to the time of one reversal by the second method or when the handle of the battery reverser is rotated very slowly by the second method.

MEASUREMENTS OF INSULATION RESISTANCE. In making the measurements of insulation resistance a reflecting galvanometer (such as

our No. 5369 Portable Reflecting Galvanometer Type H) can be used by connecting it to the post marked Ga. and disconnecting the flexible leads adjacent thereto which run to the horizontal galvanometer, or when approximate tests have to be made the galvanometer of the set can be employed by connecting the above mentioned flexible leads to the post marked Ga. In like manner an auxiliary battery can be connected to the post marked Ba., or the battery of the testing set can be employed by connecting the number of cells required to the flexible cords adjacent to Ba. After making the connections indicated above, the handles of the two double-pole double-throw switches are placed in the direction of the letters C or I. The two leading wires from the cable conductor and from the ground are connected to "Cable Posts." Insert plugs into the two holes marked I and see that no plugs are inserted in the holes marked C, G and H. The test can now be made in the ordinary manner as follows:

Close the battery circuit by means of the key Ba. and its accompanying locking device. Shortly before the period of electrification, which is generally one minute, has elapsed, press down the key marked Ga. to remove the short-circuit from the galvanometer, when the deflection can be read. Then disconnect the leading wires from the cable conductor and in like manner measure the deflection due to the leading wires, which must be subtracted from the observed deflection first read to give the true deflection due to the cable.

A shunt plug can generally be placed at I, but if the insulation is low the $\frac{1}{10}$ or $\frac{1}{100}$ shunt may have to be used, when the deflection must be multiplied by 10, or 100 respectively to get the true deflection.

The iusulation constant of galvanometer is next determined, as follows:

Remove the plug from the hole marked $\frac{1}{10}$ megohm and insert a plug at G. Use whatever shunt will give the best readable deflection, which we will call D′. Then the insulation constant of galvanometer $= \frac{D'}{10 \times \text{Shunt used}} = G$

Letting $D =$ the true deflection due to the cable,

Letting $L =$ the length of the cable in feet,

Then,

The absolute insulation resistance of the cable $= \frac{G}{D}$

and the insulation resistance per mile $= \frac{G \times L}{D \times 5280}$

It is best to make the regular insulation resistance test with the $\frac{1}{10}$ megohm in series, and this is done by removing the plug from the hole marked $\frac{1}{10}$ megohm. Where great accuracy is desired the $\frac{1}{10}$ megohm can be subtracted from the calculated absolute insulation resistance to get the true insulation resistance. This is advised so that the battery can never be short-circuited.

THE DETERMINATION OF ELECTRIC POLARITIES. To measure unknown polarities such as those of electric street railroad currents on water pipes or cables, connect the wires of the terminals whose polarity is desired to the posts marked "Ba" and make the connections to determine the constant of galvanometer as explained under "Measurements of Insulation Resistance." A deflection of the galvanometer needle towards the plus sign indicates a positive terminal at the plus "Ba" post or a deflection away from the plus sign indicates a negative terminal at the plus "Ba" post. In like manner voltages can be measured by first calibrating the galvanometer by means of a cell of known E. M. F.

MEASUREMENTS OF CONDUCTOR RESISTANCE. Place the handles of the two double-pole double-throw switches in the direction R or M or V, insert a plug in the hole marked R, and at the same time see that no plugs are in the holes marked M or V. It will be noted that there are four resistances, viz: 1, 10, 100, 1000 ohms. Any one of these can be used in the test by removing its corresponding plug, and inserting plugs in the other three holes. Before commencing the test a resistance near to the probable resistance to be measured should be left unplugged. For instance, if 5 ohms or less have to be measured the 1 ohm resistance should be left unplugged. If the probable resistance to be measured lies between 5 and 50 ohms the 10 ohms resistance should be left unplugged, if the resistance to be measured lies between 50 and 500 ohms the 100 ohms resistance should be left unplugged. If the resistance to be measured is over 500 ohms the 1000 ohms resistance should be left unplugged.

Connect in the resistance to be measured to the posts L & K. By means of the flexible cords opposite the posts marked Ba. connect a few cells of battery at first, and if necessary the whole 12 cells later. Connect the flexible cords opposite the posts marked Ga. to said posts. For the commencement of the test the $\frac{1}{10}$ shunt can be used, and for the final adjustment the 1 shunt.

The test can now be made by first placing the arms of the "Tens" and "Units" dials at zero and moving the "Hundreds" dial to 5. Press down first the battery key, and instantly thereafter the galvanometer key, and note the direction in which the galvanometer pointer moves. If the battery flexible cords have been connected as indicated by the corresponding plus and minus signs a deflection of the galvanometer towards the plus sign indicates that the dial resistance must be increased, while, if the deflection is in the opposite direction, the dial resistance must be decreased. With this information in mind, an instant only is required to determine between which two sets of "Hundreds" the balance point lies. Having found this, place the pointer at the lowest of the two, and in like manner determine between which two sets of "Tens" the balance point lies, placing the switch at the lowest of these. The final balance can then be found by rotating the "Units" switch until a point is reached when there is no deflection of the galvanometer. With the "Tens" and "Hundreds" switches the reading is taken between the two contact arms while with the "Units" switch the reading is taken at the segment with which the rotating arm is in contact.

Letting R = the unplugged resistance to the right of the double switches,

And,

Letting A = The reading of the dial switches arranged in the order of hundreds, tens, units,

the resistance to be measured $= \frac{A}{1000-A} \times R$ ohms.

The value of the term $\frac{A}{1000-A}$ can be found in the accompanying table when it is only necessary to multiply said values by the amount of resistance unplugged.

MURRAY LOOP METHOD OF LOCATING GROUNDED OR CROSSED WIRES. This is the simplest method of locating grounds or

crosses, and is applicable when the faulty and good wire are of the same size and length; hence it can be used to locate such faults in telephone and telegraph cables where all the conductors seldom become faulty before the method can be applied. It can also be used in the case of an electric cable where the outgoing and incoming cable are the same size and length, and where one of them is not faulty. To apply this method join the faulty and good conductor at the distant end of the cable and connect the faulty conductor to L and the good conductor to K. Place the two double-throw double-pole switches in the direction of R or M or V, insert plugs in the two holes marked M, and be sure that no plugs are in the two holes marked respectively V and R. The resistances 1, 10, 100 and 1000 can be either plugged or unplugged without effecting the test. Connect the ground, or in the case of a cross the wire crossed with the one used in the test, to the post marked Gr. The galvanometer and battery are connected in the same manner described under "Measurements of Conductor Resistance." The description there giving the operating of dial switches is exactly the same as must be followed in this case.

Letting A = the reading of the dials which gives a balance of the galvanometer,

L = the total length of the circuit = twice the length of the cable if the good and bad wires are in the same cable,

Then,

The distance to the fault from the post L $= \frac{A \times L}{1000}$

A check method can now be applied by connecting the faulty conductor to K and the good conductor to L.

Letting A′ = The reading of the dials which gives a balance,

$1000 - A'$ should $= A$

and therefore,

$\frac{1000 - A'}{1000} \times L$ = the distance to the fault by the check method.

When dealing with faults of high resistance 50 or more cells of battery may have to be used. Said battery should be connected to the posts Ba., and the corresponding flexible cords should be disconnected from the battery of the set.

VARLEY LOOP METHOD OF LOCATING CROSSED OR GROUNDED WIRES. Join the faulty and good conductor at the distant end of the cable, and at the near end of the cable connect the former to the post marked L and the latter to the post marked K. Then measure the resistance of the circuit as described under "Measurements of Conductor Resistance."

Let r = said resistance.

Place the handles of the two double-throw double-pole switches in the direction of R or M or V. Insert plugs in the two holes marked V, and see that no plugs are in the two holes marked respectively M, R. Join the faulty and good wires at the distant end of the cable and connect the former to L and the latter to K, connect the ground or in the case of a cross, the wire crossed with the one used in the test, to the posts marked Gr. Unplug the resistance marked 100 and plug the resistance marked 1, 10 and 1000, connect the battery and galvanometer and operate the dial switches in the same manner described

under "Measurements of Conductor Resistance." If the balance cannot readily be obtained it may be necessary to unplug the 10 ohm or perhaps the 1 ohm, the other three resistances must, of course, be plugged. The dial switches are now operated as described under "Measurements of Conductor Resistance" until a balance is obtained, when the reading is recorded.

Let R = the resistance unplugged in the Rheostat,

Let r = the resistance of the faulty and good wires,

Let A = the reading of the dials which gives a balance of the galvanometer,

And,

Let B = 1000—A,

Let a = the resistance to the fault from L,

Then,

$$a = \frac{A \times (r + R)}{A + B} = \frac{A \times (r + R)}{1000}$$

CHECK METHOD. Connect now the faulty wire to K and the good wire to L, and proceed in the same manner to find the new values A, B, R and a, which for the check method we will call A′, B′, R′ and a′.

The resistance to the fault from $K = a' = \frac{B' \times r - A' \times R'}{A' + B'} = \frac{B' \times r - A' \times R'}{1000}$

Let b = the resistance of the faulty wire = ½ the resistance of the loop where good and bad wires are of the same size and are in one cable.

Let L = the length of cable.

Then,

The distance to the fault by the first method $= \frac{a}{b} \times L.$

The distance to the fault by check method $= \frac{a'}{b} \times L.$

METHOD OF LOCATING BROKEN WIRES BY MEANS OF A TELEPHONE AND CONTINUALLY REVERSING BATTERY CURRENT. Disconnect the flexible galvanometer wires from their posts marked Ga. Remove the flexible cord in the lid of set and attach terminals of same to telephone and posts marked Ga. Place the shunt plug at 1, place the handles of both the double-throw double-pole switches in the direction of the letters R or M or V, insert two plugs in the holes marked M. Plugs must not be inserted at either V or R. It is immaterial whether or not plugs are inserted in the resistance 1, 10, 100 or 1000. The keys marked Ba. and Ga. must be held down in place by means of their locking device.

Connect the broken wire to the post marked K and a good wire in the same cable to the post marked L. If possible all the other wires should be grounded to the lead of the cable as well as the section of the broken wire beyond the break. In a telephone cable it is best to use the mate of the faulty wire for the good wire mentioned above which is connected to the post L.

The test can now be made in the following manner:

Place the rotating switches marked "Tens" and "Units" at zero, then rotate the battery reversing switch (which is placed on the main plate to the right of keys; when the same is not used, the arrow on the side should always be made to coincide with the arrow stamped on the plate), and having placed the telephone to the ear rotate the dial switch marked "Hundreds" until a point is found where the noise in the telephone is least.

The next step is to rotate the switch marked "Tens" until a position is found which gives the least sound in the telephone. In like manner the "Units" switch is rotated until no sound is observable when the required point of balance is reached.

If the sound in the telephone is not loud enough when making the final adjustment with the "Units" switch it will be necessary to used more cells of battery. The 12 cells of the testing set will, however, be enough for most purposes.

When a broken wire is to be located in a short section of cable it may be necessary to use 50 cells of battery or more, and this is done by connecting such a battery to the battery posts. It must be remembered that when the point of least sound is reached with any dial that the balance point may be either smaller or larger than the figure indicated. For instance, suppose the least sound occurs, at the point 3 of the switch marked "Hundreds," and that the sound gets louder when the switch marked "Tens" is rotated, it is conclusive that the balance is less than 300 and hence the point 2 of the "Hundreds" dial must be used. In like manner discrimination must be used between the "Tens" and "Units" switches. When a balance is obtained write down the reading in the order of "Hundreds," "Tens" and "Units."

Let said reading $= A$

Let $B = 1000 - A$

Let $L =$ the length of the cable

The distance to the break $= \frac{A}{B} \times L = \frac{A}{1000-A} L.$

The value of the term $\frac{A}{1000-A}$ can be found in the accompanying table.

This method can be very easily applied, and the results are very satisfactory. With this Testing Set, faults of this kind have been located within two or three feet in lengths of over 1000 feet of cable.

Portable Reflecting Galvanometer

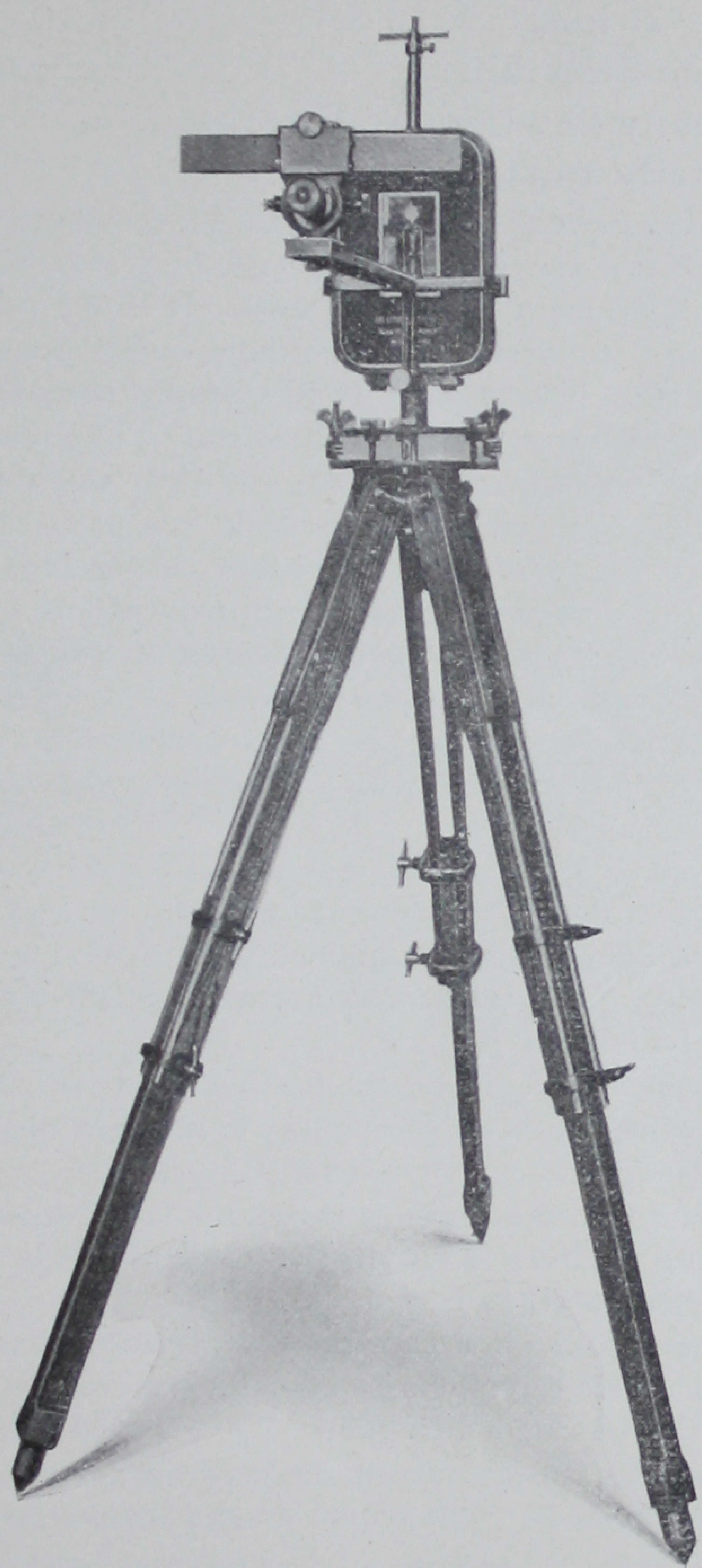


FIG. 1

No. 5369

5369. Portable Reflecting Galvanometer, Type H $125.00

Complete with reading telescope and scale, high tripod, carrying case and repair kit.

In this galvanometer we have been successful in combining in a way which we believe has not heretofore been approached, the three requisites of a portable cable testing galvanometer. It has

Ample Sensibility,
Is easily Set Up and Operated,
Is easily Portable.

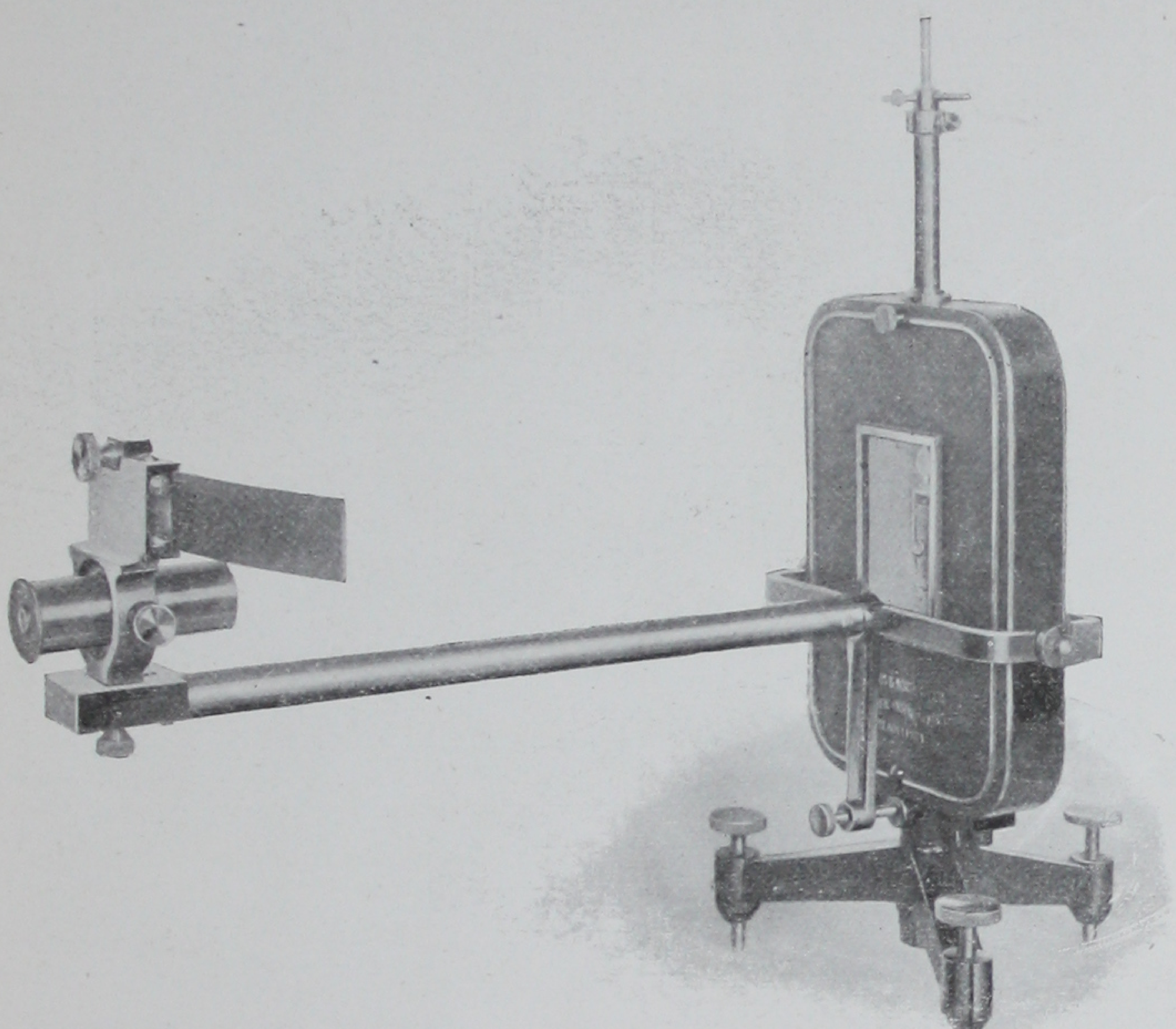
It was designed to meet the demand for a high sensibility, portable galvanometer arranged for use under conditions and in places where the ordinary laboratory type of instrument cannot be used. It is our type H, D'Arsonval Galvanometer arranged to meet these conditions, and it preserves all the good working qualities of that instrument. **It has ample sensibility, is quick in its action, has a positive zero and is deadbeat. The working parts are arranged so that they can be easily seen and they can also be easily gotten at for repairs.** A repair kit containing two pairs of pliers, a watchmaker's screw driver and extra upper and lower suspensions is furnished with each instrument. Fig. 1 shows the instrument mounted on its tripod.

The reading telescope is of a special design of unusually high magnifying power. Although the telescope arm is only 15″ long and the scale 21 cm. long, the magnifying power is such that the appearance is the same as that of a scale at a meters distance viewed with an ordinary telescope. The scale has 250 divisions each side of the zero.

This optical system is one which makes it particularly easy "to find the scale," and in setting the instrument up, no delay is occasioned in getting it properly adjusted and focused. The tripod is of the best construction used in surveying instruments. **The clamping screws are all made so that they cannot drop out and be lost.**

The galvanometer is clamped on the head of the tripod by two wing nuts. To remove the instrument it is only necessary to unscrew these a few turns and throw them out. The galvanometer is levelled in the ordinary way by levelling screws. The coil and mirror are visible through a large window and they serve as a guide in levelling. **There is ample clearance and it is very easy to determine when the coil swings free.**

The Galvanometer packs in a carrying case, as shown in the illustration of No. 5375 (page 46). This carrying case contains the complete instrument with the exception of the tripod, which folds up. The galvanometer box is 20″ high by 11″ wide and 8¾″ deep. Complete with the galvanometer mounted in it, it weighs about 38 pounds. The tripod weighs about 10 pounds.



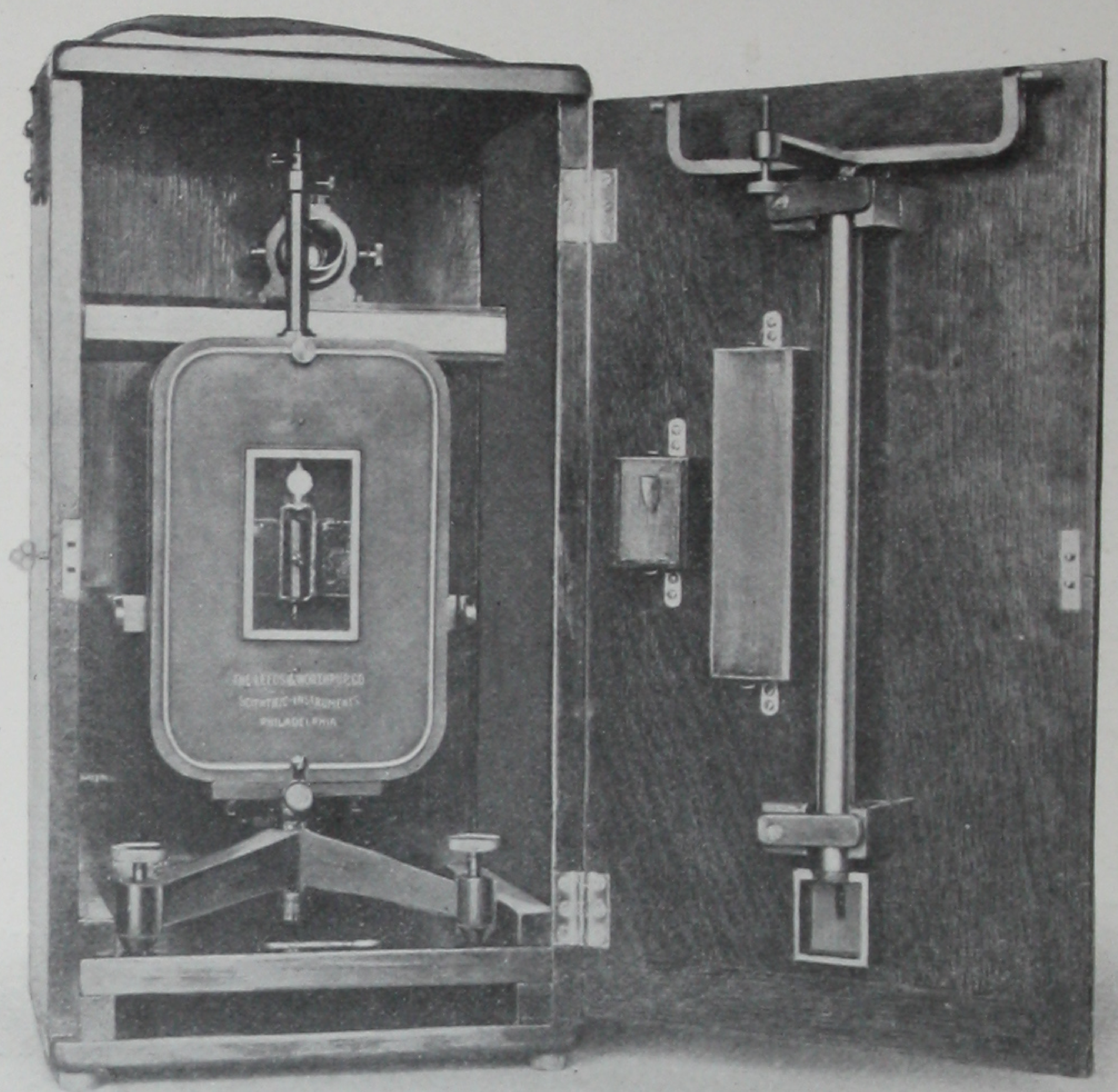
No. 5375

(See also illustration on page 46)

5375. **Semi-Portable Reflecting Galvanometer, Type H** $100.00

Complete with reading telescope and scale, carrying case and repair kit.

This is the same as No. 5369 except that it is not mounted on a high tripod. It is an easily portable instrument and is very easily set up and is available for use wherever there is a suitable support for it.



No. 5375 Mounted in Case

Portable Insulation and Capacity Testing Set

5380. Leeds & Northrup Portable Insulation and Capacity Testing Set $265.00

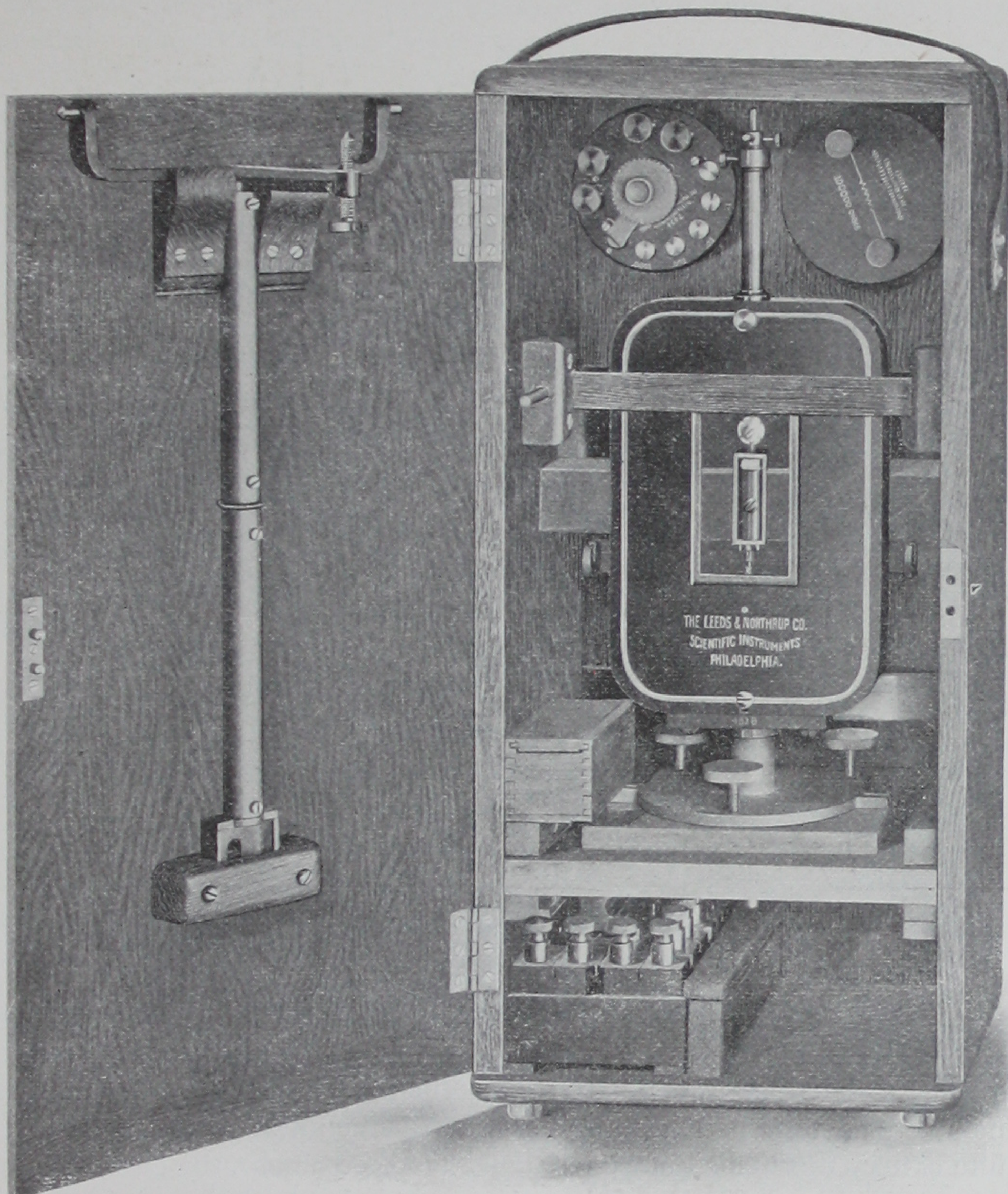
This outfit combines the advantages of the portable combination sets with those of sets made up of a number of individual instruments.

Like the former it is

Very easily portable,
Simple to manipulate.

Like the latter

The parts may be very highly insulated from each other,
Liability to break down is reduced to a minimum.



No. 5380

It consists of the following pieces of apparatus. They mount for easy portability in the galvanometer case as shown in the illustration.

1—5369 Portable Reflecting Galvanometer, Type H . .	$125.00
1—5390 Ayrton Shunt and Battery key, shunt points 1, 0.1, 0.01, 0.001, 0.0001	45.00
1—5391, 100,000 Ohm Standard	45.00
1—5392, $\frac{1}{3}$ Micro-farad Standard Condenser, with Condenser Switch.	50.00

The above makes a complete outfit (with the exception of battery) for measuring the insulation and capacity of cables.

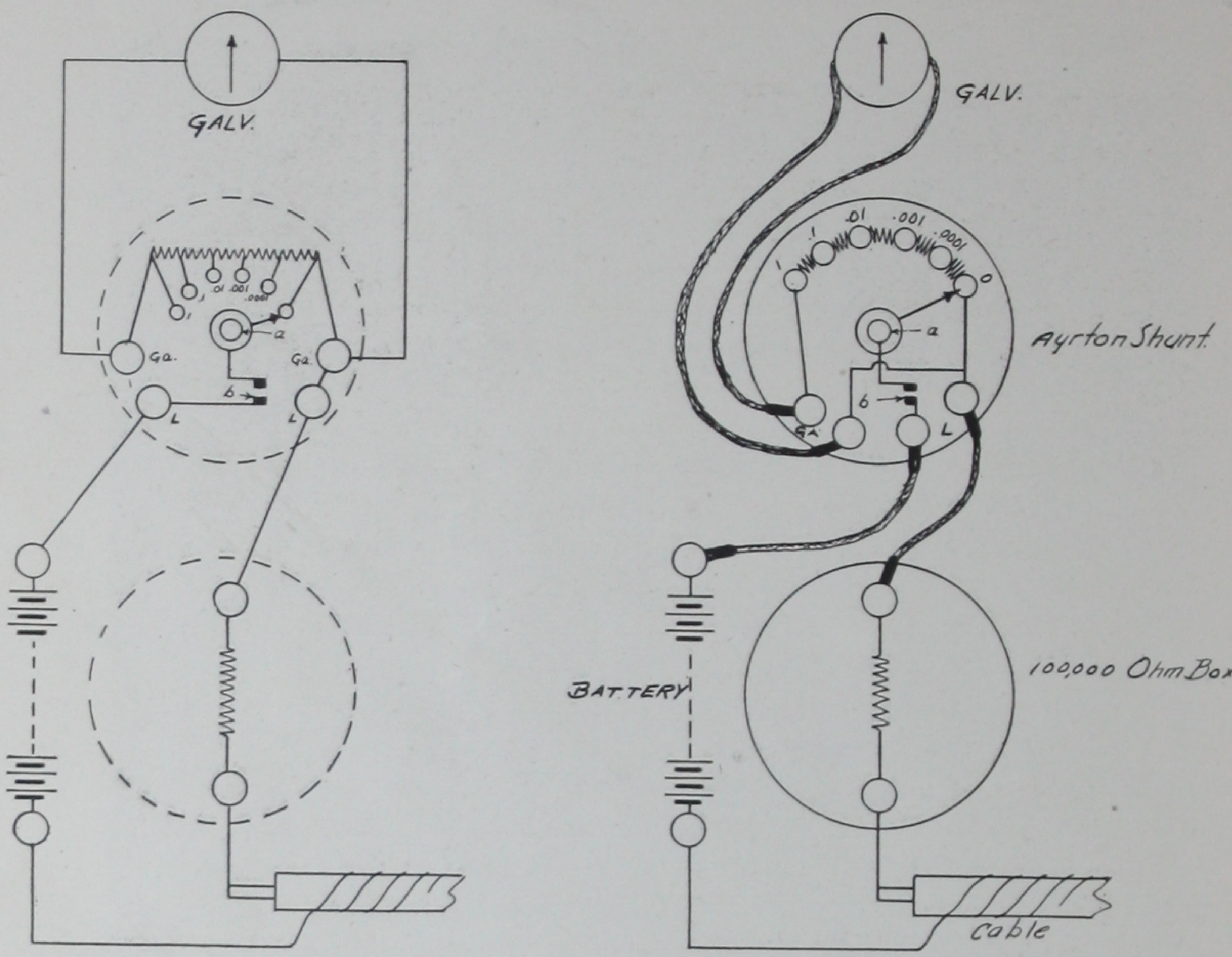


Diagram of connections for insulation measurement

INSULATION MEASUREMENTS are to be made with the apparatus as shown in the diagram.

In general, the usual direct deflection method is used. The constant of the galvanometer is determined by observing the deflection due to the current from a definite battery through a known resistance (100,000 ohms), the galvanometer being shunted. The deflection of the galvanometer due to the current from the same battery through the insulation resistance to be measured is observed, and from these two deflections the insulation is calculated.

The apparatus and arrangement differ from that usually employed,

1st. In that the battery key is combined with the shunt,

2nd. In that there is no short-circuit key for the galvanometer.

The battery key b is combined with the Ayrton Shunt for compactness and also for convenience in manipulation. The knob a controls the key b and is mounted so that it projects up through the handle which operates the shunt. By depressing a, the contact b is closed. This is arranged so that it can be locked in the closed position.

The galvanometer short-circuit key is omitted partly in the interest of simplicity of working and compactness, and primarily to avoid the bad effects due to using a short-circuit key with a damped D'Arsonval Galvanometer. As is well known, a D'Arsonval Galvanometer damped to give a satisfactory period

of deflection becomes exceedingly unsatisfactory and sluggish when it is short-circuited. The necessity for using a short-circuit key is avoided by connecting the shunt as shown in the diagram. With the shunt switch on the position zero, the galvanometer is out of the circuit and no current passes through it. The battery key being closed, the course of the current is from one side of the battery through the insulation of the cable (or the 100,000 ohm box as the case may be) to Ga. through a and b, to the other side of the battery. This is the position used during the period of electrification of the cable.

This arrangement has the additional advantage of protecting the galvanometer against excessive deflection when a leaky cable is under investigation. The galvanometer deflection is taken by moving the shunt from the position zero toward the position 1, and in the case of a leaky cable, there would be a small deflection with the shunt on the position .0001 or .001, and the excessive deflection which the unshunted galvanometer would get could be avoided.

The shunt may be held in one hand while its handle and the knob a are manipulated in the other. This is the customary method of working. In order to make it entirely free from leakage, the shunt is mounted in a hard rubber case.

The 100,000 ohm box is arranged without any provision for shortcircuiting the resistance. This is done because in the great majority of cases, it is not necessary to make any correction for the addition of 100,000 ohms to the insulation under measurement. In a few cases where the correction is necessary, it can be made, or the two binding posts can be connected by a piece of wire to cut out the resistance.

The simplicity of the arrangement and its operation will be made entirely clear from the following directions for making measurements.

Directions for Insulation Measurements

Connect a suitable battery (100 cells) as shown in the diagram drawing, connecting one terminal of the battery directly to the 100,000 ohm box instead of to the cable. Close battery key b by depressing a and move the shunt to the position .0001. With 100 cells of battery, the galvanometer will now give a readable deflection. Call this deflection D′ and the shunt position S′, then the insulation constant of the galvanometer in megohms will be

$$\frac{D'}{10 \times S'}$$

For instance, if D′ = 80 and S′ as above = .0001, then

$$\text{Const.} = \frac{80}{10 \times .0001} = 80{,}000 \text{ megohms.}$$

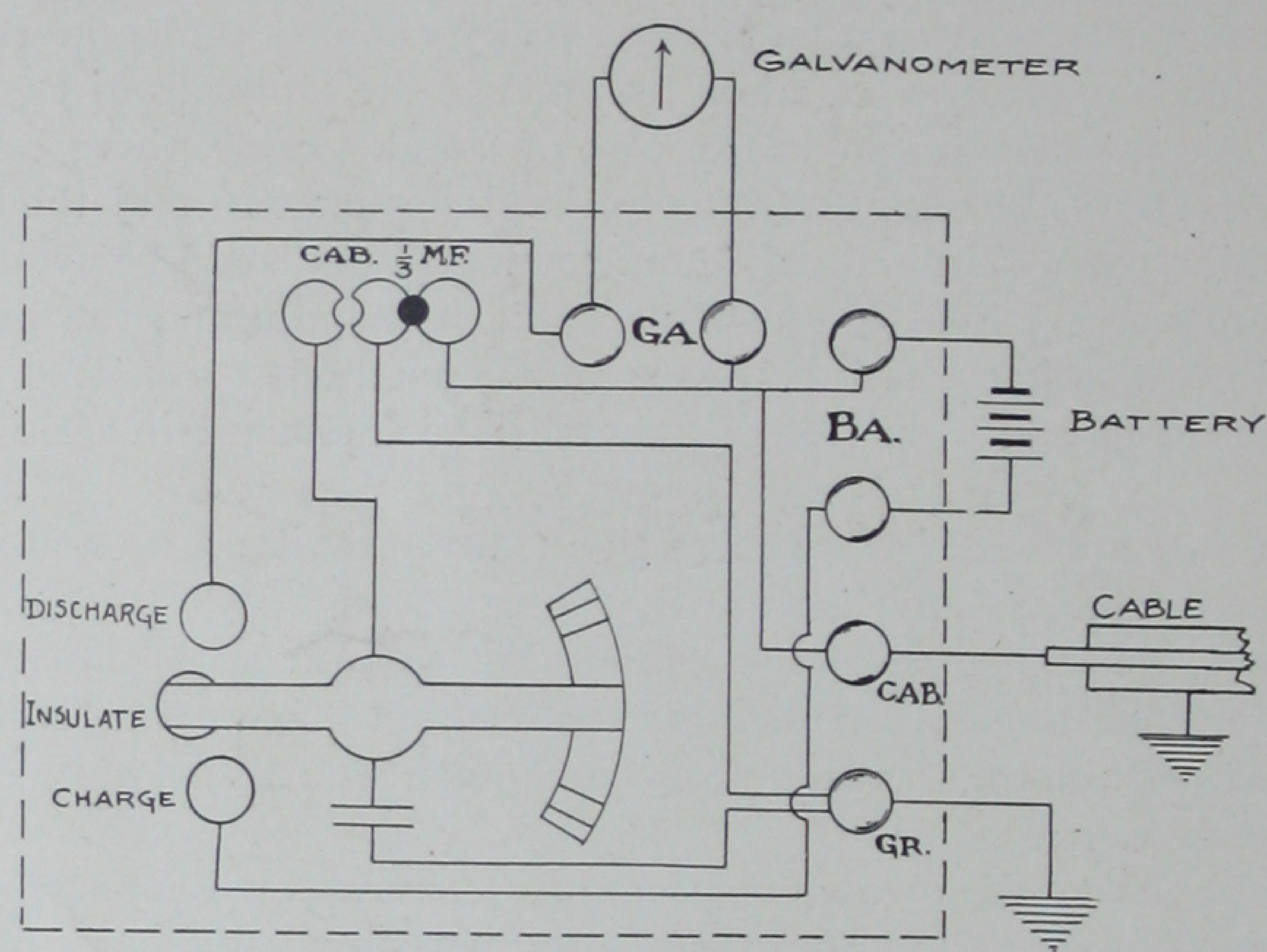
To determine the insulation of the cable, reset the shunt at the position zero and connect in the cable as shown in the diagram. Close the battery key b and after allowing a sufficient period for electrification to elapse, move the shunt successively over the position .0001, .001, .01, .1 to 1, observing the galvanometer to see that it does not give too large a deflection. When a readable deflection is gotten, note it and the shunt position. Call this deflection D and the shunt position S, the insulation I to be determined will then be

$$I = \frac{\text{Const.} \times S}{D}$$

If, for example, the deflection D is 40 and the shunt position S is I, the constant as above determined being 80,000, then

$$I = \frac{80{,}000}{40} = 2{,}000 \text{ megohms.}$$

Measurement of Electrostatic Capacity



For this purpose No. 5392 one third micro-farad standard condenser and condenser switch are used. The construction of this and the method of operating it are clearly shown in the diagram. The case is made entirely of hard rubber and the parts are very well insulated so it may be held in the hand without danger of error while making a test.

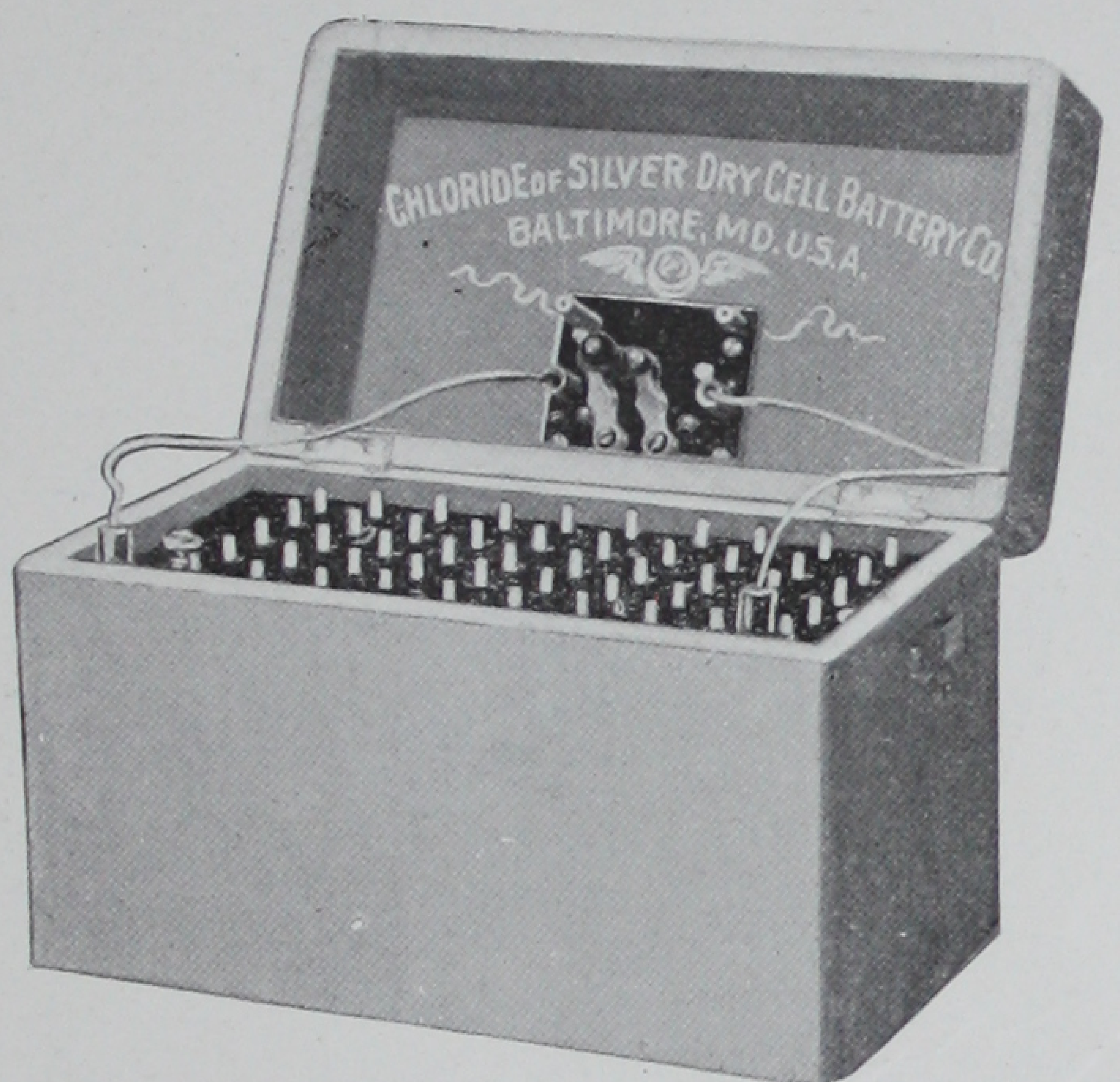
The method is the usual one of comparing the discharge from the cable with that from the standard condenser. Although the galvanometer is damped the deflections are strictly proportional to the capacities. With a plug in the position "Cab.", the deflection due to the cable can be taken, and with it in the position "⅓ M. F.", that due to the standard condenser can be taken.

Portable Insulation Testing Set

5385. **Leeds & Northrup Portable Insulating Testing Set** $215.00

This is the same as No. 5380 except that it does not include No. 5302 standard one-third micro-farad with condenser switch.

"Chloride of Silver" Portable Dry Cell Testing Batteries



No. 5555

These batteries are highly recommended for "testing" purposes. The cells are hermetically sealed, so that there is no spilling of acid. Any number of cells from 1 up to maximum capacity of battery can be used, by means of connecting cords which are provided. The E. M. F. is about .9 volt per cell.

	COMPLETE	Dimensions	Weight		Net Price
No. 5552	100 Cell Testing Battery,	11¼x11¼x7½	about 21	lbs.	$90.00
" 5553	84 Cell Testing Battery,	11¼x11¼x7½	" 19	"	75.00
" 5554	60 Cell Testing Battery,	13 x 6¼x7⅜	" 14	"	55.00
" 5555	50 Cell Testing Battery,	11⅛x 6¼x7¼	" 12	"	45.00
" 5556	40 Cell Testing Battery,	12 x 5⅝x7	" 10	"	40.00
" 5557	32 Cell Testing Battery,	10⅛x 5¾x7¼	" 8¾	"	35.00
" 5558	24 Cell Testing Battery,	10⅛x 5¾x7¼	" 8	"	25.00
" 5559	16 Cell Testing Battery,	6⅝x 5⅜x5½			16.00
" 5560	12 Cell Testing Battery,	5¾x 5½x5½			12.00
" 5561	6 Cell Testing Battery,	4⅜x 4½x5½			8.00

The 16, 12, and 6 Cell Batteries are without Pole Changers.

"Clover Leaf" Test Sets

For Insulation Testing, Potentiometer and Wheatstone Bridge Work, Laboratory Measurements, Etc.

The "Clover Leaf" Test Cells are put up in soldered zinc shells, with a positive electrode of Carbon and are absolutely dry cells. They do not leak or burst, and consequently cannot injure delicate instruments with wet chemicals. They are made of the finest materials and with great care. The E. M. F. of each cell is 1.5 volts. These cells are made up into Test Sets or Batteries of 25, 50, 75 and 100 cells, contained in a handsome polished mahogany case fitted with lock and leather handle. The cells are mounted and connected in the most perfect manner, and in such a way that any cell can easily be inspected or replaced when necessary.

Each set is provided with a Reversing Switch of the most approved form and with double grip binding posts. They are unsually light and compact.

Dimensions and Price List of "Clover Leaf" Test Sets

Total No. of Cells	100	75	50	25
No. of Active Cells	99	74	49	24
Weight	15 lbs.	11 lbs.	7¾ lbs.	4½ lbs
Dimensions	9¾ x 9¾ x 4⅜	14 x 5⅜ x 4⅜	9¾ x 5⅜ x 4⅜	5⅜ x 5⅜ x 4⅜
Total Voltage	148.5	111	73.5	36
Price	$85.00	$65.00	$45.00	$25.00

Single Cells, each $0.60.

We publish the following catalogues and descriptive pamphlets of our Electrical Testing Instruments. Any of these will be sent on request to those interested.

The LEEDS & NORTHRUP CO.

CATALOGUE

of Electrical Testing Instruments, 92 Pages

PAMPHLETS:

No. 1. Resistance Boxes

No. 2. Potentiometers

No. 3. Moving Coil Galvanometers

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No. 5. Portable Testing Sets and Cable Testing Apparatus

No. 7. High-Grade Keys for Electrical Testing

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